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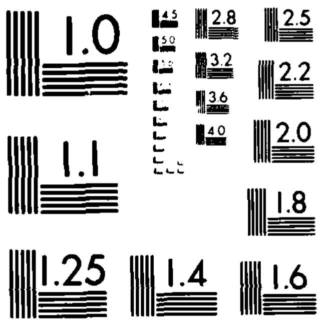
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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A SIMULATION STUDY OF MODELS
FOR
COMBINATIONS OF RANDOM LOADS

by
Noh, Jang Kab

September 1984

Thesis Advisor: P.A. Jacobs

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This thesis describes a model for a combination of random loads acting upon a physical structure, such as a building or ship. The various loads represented in a model might be winds, tidal effects, or even earthquakes or snow loading. Asumptotic results are given for the first-passage time for the load combination process to exceed a given stress level exceeding structural strength. The accuracy of using the asymptotic results to approximate the first-passage time, or time to structural failure, distribution is assessed by simulation.

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A Simulation Study of Models for Combinations of Random Loads

by

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B.S., Korea Air Force Academy, 1974

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I. <u>DESCRIPTION OF A STOCHASTIC MODEL FOR COMBINATIONS OF RANDOM LOADS</u>

Many physical structures are threatened by combinations of loads of varying magnitudes from various sources. For instance, bridges, piers, dams, and buildings can experience loads from wind, snow, ice, tides, earthquakes, and so forth. In many instances the total load or stress experienced by a structure varies in time in an apparently random fashion. Certain components of the loads vary rather slowly; others occur more nearly as impulses, such as those associated with winds or earthquakes. The problem is to design a structure to withstand the superposition of random loads from many sources with at least an approximately understood probability.

The purpose of this thesis is to describe and investigate certain simple but somewhat realistic probabilistic load models for use in design, and perhaps safety assessment of structures. In this thesis we confine attention to the superposition of just two load types; <u>shock loads</u>, and <u>constant loads</u>. For example, winds gusts, flash floods, and earthquakes have varying magnitudes and have relatively short durations in comparison to the times between their occurrences. These will be modelled as instantaneous shock loads. On the other hand, snow, ice, or water accumulation, or even the presence of slowly moving vehicles present loads that remain nearly constant in time, occasionally changing to new levels. These will be modeled as constant loads that change infrequently. Throughout this investigation it will be assumed that the effective stress exerted by several types of loads acting simultaneously can be expressed as a linear combination of the component loads, the load components being treated as stochastic processes.

The times between changes in magnitude of the constant load process are independently and identically distributed with distribution function H. The successive magnitudes of the constant load are independently and identically distributed with distribution function F. Given the constant load process, the shock load process is a compound Poisson process. The successive shock load magnitudes are independently and identically distributed with distribution function G. The conditional rate of arrival of shocks, given that the magnitude of the constant load process is x, is $\mu(x)$.

Let X(t) be the magnitude of constant load process at time t; and Y(t) be the magnitude of shock load process at time t; $Z(t)=X(t)+Y(t)$ is the superposition of the two loads at time t, and $M(t)=\sup_{s\le t} Z(s)$, the maximum load combination in $[0,t]$, see figure 1.1.

Let $T_x=\{\inf t\ge 0: Z(t)>x\}$ ie, the first-passage time for the load combination to exceed a stress level x. T_x will represent the time to failure of a structure whose strength is x, and is subjected to a stress history $\{Z(t);\ t\ge 0\}$.

Gaver and Jacobs (1981) studied the above model for the case in which the distribution H is exponential and the shock load rate μ is a constant independent of the shock load process. Related load combination models that have been studied include Peir and Cornell (1973) [Ref. 1] Wen (1977) [Ref. 2] Pearce and Wen (1983) [Ref. 3].

Asymptotic results which appear in Gaver and Jacobs (1984) and Jacobs (1984) will be described in chapter 2 for the distribution of T_x as $x\to\infty$ and for the tail of the distribution of T_x for finite x.

In chapter 3, a simulation program for the load combination model will be described.

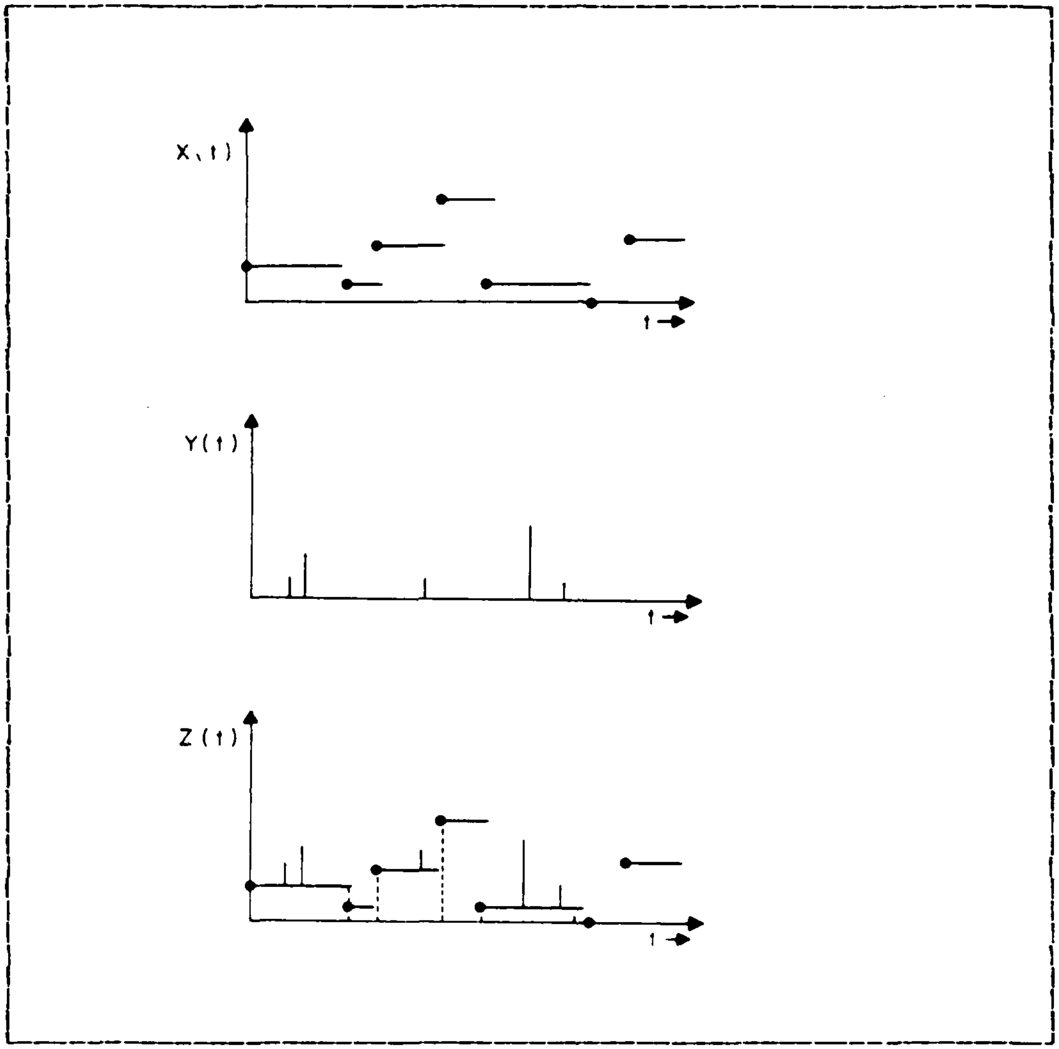

Figure 1.1 The Load Combination Process.

In chapter 4, a simulation study of the use of the asymptotic results of chapter 2 to approximate the distribution of T_X will be described.

II. ASYMPTOTIC RESULTS FOR THE DISTRIBUTION OF THE FIRST-PASSAGE TIME T_x

A. THE DISTRIBUTION OF T_X FOR LARGE X

This section summarizes some of the results found in Gaver and Jacobs (1981) [Ref. 4] for the model in which the distribution H is exponential(λ) and the shock load arrival rate μ is constant independent of the constant load process.

First, we consider the distribution function of the maximum load combination to occur during [0,t], M(t).

$$H_x(t)=P\{M(t)\le x\}$$
$$=P\{M(t)\le x, T_1>t\}+P\{M(t)\le x, T_1<t\} \quad \text{----------- (2-1)}$$

where T_1 is the arrival time of the first shock.

A renewal argument yields;

$$P\{M(t)\le x, T_1>t\}=e^{-\lambda t}\int_0^x \exp(-\mu t\,\bar{G}(x-y))\,F(dy)$$
$$P\{M(t)\le x, T_1<t\}=\int_0^t \lambda e^{-\lambda v}dv\int_0^x \exp(-\mu v\,\bar{G}(x-y))\,H_x(t-v)\,F(dy)$$

where $\bar{G}(x)=1-G(x)$.

Next take Laplace transforms with respect to t of (2-1).

$$\hat{H}_x(\xi)=\int_0^x e^{-\xi t}H_x(t)\,dt$$
$$=M_x(\xi)+\lambda M_x(\xi)\hat{H}_x(\xi) \quad \text{------------------------- (2-2)}$$

where

$$M_x(\xi)=\int_0^x[\xi+\lambda+\mu\bar{G}(x-y)]^{-1}F(dy) \quad \text{------------------------ (2-3)}$$

Hence

$$\hat{H}_x(\xi)=\frac{M_x(\xi)}{1-\lambda M_x(\xi)} \quad \text{--------------------- (2-4)}$$

It seems to be difficult to invert $\hat{H}_x(\xi)$ for any interesting choice of the distributions F(x) and G(x). However, useful information can still be gleaned from equation (2-4). First, from the definition of T_x,

$$P\{M(t)\le x\}=P(T_x>t) \quad \text{----------------------------- (2-5)}$$

Thus, $\hat{H}_x(\xi)=\int_0^\infty e^{-\xi t}P(T_x>t)\,dt$ -------------------- (2-6)

Let $\xi\to 0$, in equation (2-6) to find that

$$m(x) = E(T_x) = \hat{H}_x(0) = \frac{M_x(0)}{1 - \lambda M_x(0)} \quad \text{------------- ---- (2-7)}$$

The next result is the limiting property for the first time the load combination process exceeds a given level x. The limiting distribution of T_x is exponential in the sense that

$$\lim_{x \to x_0} P\{m(x)^{-1} T_x > t\} = e^{-t} \quad \text{--------------- (2-8)}$$

where $x_0 = \inf\{t; F*G(t) = 1\}$

The proof of this result for a more general model that includes that of chapter 2 can be found in Jacobs (1984) [Ref. 5].

B. THE TAIL OF THE DISTRIBUTION OF T_x FOR FINITE X

In this section we will summarize results for the asymptotic behavior of $P(T_x > t)$ for large t and fixed x as $t \to \infty$ for the model in which the distribution H is exponential and the shock load arrival rate is constant. More details and results for a more general model that includes that of chapter 2 can be found in Jacobs (1984).

From the equations (2-1) and (2-5)

$$P(T_x > t) = e^{-\lambda t} \int_0^x F(dy)\, e^{-\mu \bar{G}(x-y)t} + \lambda \int_0^t e^{-\lambda s}\, ds \int_0^x F(dy)\, e^{-\mu \bar{G}(x-y)s}\, P(T_x > t-s) \quad \text{----- (2-9)}$$

let

$$L(ds) = \int_0^x F(dy)\, \lambda e^{-[\lambda + \mu \bar{G}(x-y)]s}\, ds \quad \text{------- (2-10)}$$

$$I(t) = \int_0^x F(dy)\, \frac{\lambda}{\lambda + \mu \bar{G}(x-y)} \left\{1 - e^{-[\lambda + \mu \bar{G}(x-y)]t}\right\} \quad \text{------- (2-11)}$$

$$I(\infty) = \int_0^x F(dy)\, \frac{\lambda}{\lambda + \mu \bar{G}(x-y)} \quad \text{------- (2-12)}$$

The renewal equation (2-9) gives;

$$P(T_x > t) = g(t) + \int_0^t L(ds)\, H_x(t-s) \quad \text{--- --- (2-13)}$$

where $g(t) = \int_0^t F(dy)\, e^{-[\lambda + \mu \bar{G}(x-y)]t}$ -------- (2-14)

Following the development in Feller (1971; page 376) [Ref. 6] it will be assumed that there exists a number κ such that

$$1 = \int_0^\infty e^{\kappa(x) y}\, L(dy) \quad \text{-------------------- (2-15)}$$

This root is unique and since the distribution of I is defective, is positive.

Let

$$L^{\#}(ds) = e^{\mathcal{K}(x)s}\, L(ds) \qquad \text{------------------ (2-16)}$$

$$g^{\#}(t) = e^{\mathcal{K}(x)t}\, g(t) \qquad \text{------------------ (2-17)}$$

$$P^{\#}(T_x > t) = e^{\mathcal{K}(x)t}\, H_x(t) \qquad \text{------------------ (2-18)}$$

Then

$$P^{\#}(T_x > t) = g^{\#}(t) + \int_0^t P^{\#}\{T_x > (t-s)\}\, L^{\#}(ds) \qquad \text{---------- (2-19)}$$

It is assumed that the assumption for the key renewal theorem holds. Application of the key renewal theorem yields

$$\lim_{t\to\infty} e^{\mathcal{K}(x)t}\, P(T_x > t) = \frac{1}{\gamma^{\#}} \int_0^\infty g^{\#}(t)\, dt \qquad \text{------------ (2-20)}$$

$$\int_0^\infty g^{\#}(t)\, dt = \int_0^x F(dy) \int_0^\infty e^{\mathcal{K}(x)t}\, e^{-[\lambda + \mu \bar{G}(x-y)]t}\, dt$$

$$= \int_0^x F(dy)\, \frac{1}{\lambda + \mu \bar{G}(x-y) - \mathcal{K}(x)} \qquad \text{------------ (2-21)}$$

Rewriting the equation (2-15), the equation determining $\mathcal{K}$ is

$$1 = \int_0^\infty e^{\mathcal{K}(x)s} \int_0^x F(dy)\, \lambda\, e^{-[\lambda + \mu \bar{G}(x-y)]s}\, ds$$

$$= \int_0^x F(dy)\, \frac{\lambda}{\lambda + \mu \bar{G}(x-y) - \mathcal{K}(x)} \qquad \text{------------- (2-22)}$$

and

$$\gamma^{\#} = \int_0^\infty t \int_0^x F(dy)\, e^{\mathcal{K}(x)t}\, \lambda\, e^{-[\lambda - \mu \bar{G}(x-y)]t}\, dt$$

$$= \int_0^x F(dy)\, \frac{\lambda}{[\lambda + \mu \bar{G}(x-y) - \mathcal{K}(x)]^2} \qquad \text{-------------- (2-23)}$$

The key renewal theorem implies;

$$\lim_{t\to\infty} e^{\mathcal{K}(x)t}\, P(T_x > t) = \frac{1}{\lambda \int_0^x F(dy)\, \dfrac{\lambda}{[\lambda + \mu \bar{G}(x-y) - \mathcal{K}(x)]^2}} \qquad \text{------- -- (2-24)}$$

Examples:

It appears to be difficult to solve for $\mathcal{K}$ analytically in general. We will discuss the numerical computation of $\mathcal{K}$ for two examples. In both examples, $\lambda = \mu = 1$ and the distribution of the shock and constant load magnitudes F and G are of the form;

$$\bar{F}(x) = e^{-ax}$$

$$\bar{G}(x) = e^{-bx}$$

In example 1, a=b=1 and in example 2, a/b=2.

To compute the κ for $\overline{F}(x) = e^{-ax}$, $\overline{G}(x) = e^{-bx}$,

let

$$f(\kappa) = \int_0^x F(dy) \frac{\lambda}{\lambda + \mu \overline{G}(x-y) - \kappa(x)} \qquad \text{------------------- (2-25)}$$

where $\lambda = \mu = 1$.

For model 1,

$$f(\kappa) = \frac{1}{(1-\kappa)^2}\left\{(1-\kappa)(1-e^{-x}) - e^{-x}\left[\ln(1-\kappa+e^{-x}) - \ln((1-\kappa)e^{-x}+e^{-x})\right]\right\} \qquad \text{-- (2-26)}$$

for $\kappa < 1+e^{-x}$ and $\kappa \neq 1$.

For $\kappa=1$, $f(\kappa)$ has a singular point, so by using the L'HÔPITAL RULE [Ref. 7]

$$\lim_{\kappa \to 1} f(\kappa) = \lim_{\kappa \to 1} g'(\kappa)/h'(\kappa)$$

where $g(\kappa)$ is the numerator and $h(\kappa)$ is the denominator of the function $f(\kappa)$.

For $\kappa = 1$,

$$f(1) = \frac{1}{2}(e^{x} - e^{-x}) \qquad \text{---- (2-27)}$$

For model 2,

$$f(\kappa) = \frac{2}{(1-\kappa)^3}\left\{\frac{(1-\kappa+e^{-bx})^2}{2} - \frac{((1-\kappa)e^{-bx}+e^{-bx})^2}{2} - 2e^{-bx}((1-\kappa)(1-e^{-bx}))\right.$$

$$\left. + e^{-2bx}\left[\ln(1-\kappa+e^{-bx}) - \ln((1-\kappa)e^{-bx}+e^{-bx})\right]\right\} \qquad \text{----- (2-28)}$$

for $\kappa < 1+e^{-bx}$ and $\kappa \neq 1$.

For $\kappa=1$ $f(\kappa)$ has also singular point, so by using the same method as used in model 1;

for $\kappa = 1$

$$f(1) = \frac{a}{a+b}(e^{bx} - e^{-ax}) \qquad \text{---- (2-29)}$$

Differentiation of the equation (2-25) gives

$$f'(\kappa) = \int_0^x e^{-ay} \frac{\lambda}{[\lambda + \mu e^{-b(x-y)} - \kappa]^2} \qquad \text{----------- (2-30)}$$

Equation (2-30) is greater than 0 for $0 \le \kappa < 1+e^{-bx}$ and $\kappa \neq 1$. So the function $f(\kappa)$ is a monotone increasing function in the interval $0 \le \kappa < 1+e^{-bx}$. Using this result, we compute the κ from the equation (2-22) by applying the bisection method [Ref. 8].

Using the computed κ we compute the constant γ^* such that;

$$\gamma^* = \lambda \int_0^x F(dy) \frac{\lambda}{[\lambda + \mu \overline{G}(x-y) - \kappa]^2}$$

is the constant of equation (2-24).

For case a=b=1,

$$\gamma^{\#} = \frac{1}{(1-\kappa)^3}\left\{\left[(1-\kappa+e^{-x}) - 2e^{-x}\ln(1-\kappa+e^{-x}) - \frac{e^{-2x}}{1-\kappa+e^{-x}}\right] - \left[e^{-x}(2-\kappa) - 2e^{-x}\ln(e^{-x}(2-\kappa)) - \frac{e^{-2x}}{e^{-x}(2-\kappa)}\right]\right\} \quad \text{-- (2-31)}$$

For case a/b=2,

$$\gamma^{\#} = \frac{2}{(1-\kappa)^4}\left\{\frac{(1-\kappa+e^{-bx})^2}{2} - \frac{((1-\kappa)e^{-bx}+e^{-bx})^2}{2} - 3e^{-bx}((1-\kappa)(1-e^{-bx})) + 3e^{-2bx}\left[\ln(1-\kappa+e^{-bx}) - \ln((1-\kappa)e^{-bx}+e^{-bx})\right] - e^{-3bx}\left[\frac{1}{(1-\kappa)e^{-bx}+e^{-bx}} - \frac{1}{1-\kappa+e^{-bx}}\right]\right\} \quad (2-32)$$

III. COMPUTER SIMULATION

This section describes the computer simulation model. We denote the constant load arrival rate by λ, the shock load arrival rate by μ, the distribution of constant load magnitude by $F(x)$, and the distribution of shock load magnitude by $G(x)$. The simulation model will be used to study the quality of the approximations of the distribution of T_x by the asymptotic results described in chapter 2.

The following describes the simulation algorithm. The stress levels are $x_1 < x_2 < x_3 \ldots\ldots\ldots < x_n$.

1, Set $T=0$, $N_0=0$.

2, Set $V=0$, generate a constant load magnitude, C, and duration interval Tc. Find the largest index $i>N_0$ such that $x_i \le C$.
   Put N_1 equal to that index and
   set
   $T_{x_i} = T$ for $N_0 < i \le N_1$,
   set $N_0 = N_1$.

3, Generate a shock load magnitude, S, and a time until the shock occurs, Ts.

4, If the shock interval does not exceed the excess life of the constant load duration, Tc, find the largest index $i>N_0$ such that $x_i \le C+S$.
   Let N_1 be that index.
   Set $T_{x_i} = T+V+Ts$ for $N_0 < i \le N_1$.
   Set $N_0 = N_1$, $V=V+Ts$, $Tc=Tc-Ts$. Go to step 3.

5, If the shock interval exceeds the excess life time of the constant load duration,
   set $T=T+Tc$, go to step 2.

One realization of the simulation is completed when one T_x is computed for each level x_i, $1 \le i \le n$. Each simulation consisted of 5000 replications. Further details are

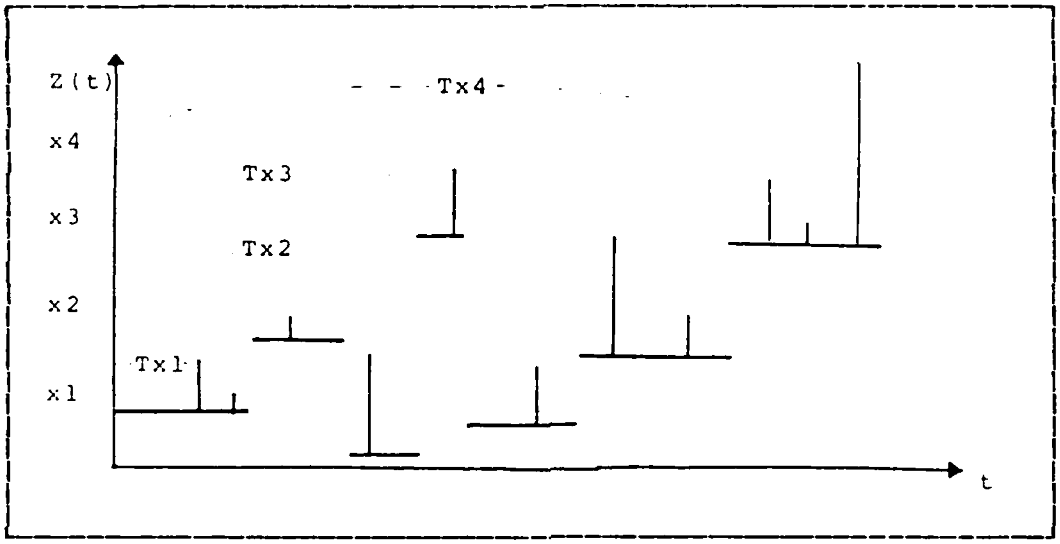

Figure 3.1 Generating T.

included in chapter 5.

The key subprograms are following. Other programs will be explained by reading from the output results.

RANDC ; generate the T_x.

COMPUT ; compute the $P(T_x=0)$, true $P(T_x=0)$, sample mean, true mean, standard deviation, coefficient of variance.

Sample probability

$P(T_x=0) = \frac{\text{number of } T_x=0}{\text{Sample size}}$ is obtained from the sample.

True probability

$P(T_x=0) = 1-P(T_x>0) = 1-P(M(0) \le x) = 1-\int_0^t F(dy) = \bar{F}(t)$ is obtained from the equation (2-5).

The sample mean

$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} T_{x_i}$ and

the true mean $E(T_x)$ is obtained in special cases from the equation (2-7).

See details in Gaver and Jacobs (1981).

Sample standard deviation

$\hat{\sigma} = \frac{1}{n-1}\sum_{i=1}^{n}(T_{x_i}-\bar{x})$ is obtained from the sample, and

Sample coefficient of variance

$C(v) = \frac{\hat{\sigma}}{\bar{x}}$ is obtained from the sample mean and sample standard deviation.

CCMP ; compute the sample quantiles, and the quantiles of an exponential distribution with mean $E(T_x)$.

A sample quantile is

$\hat{q}_\alpha = (\alpha \times \text{sample size})$ th order statistic of sample and

$q_\alpha = -E(T_x)\ln(1-\alpha)$ is the quantile of exponential distribution with mean $E(T_x)$.

CCM ; compute the quantile of the sample conditional distribution given $T_x>0$ and the exponential distribution with mean $E(T_x)/P(T_x>0)$.

The sample quantile of the conditional distribution

$\hat{q}_{\alpha c} = [\alpha \times (\text{number of positive } T_x)]$th order statistic is obtained for sample of positive T_x.

The conditional quantile of the exponential distribution with mean $E(T_x)/P(T_x>0)$ is

$q_{\alpha c} = -\frac{E(T_x)}{P(T_x>0)}\ln(1-\alpha_c)$.

SK ; compute the κ such that;

$\kappa = \{\kappa(x) : 1 = \int_0^x F(dy)\frac{\lambda}{\lambda+\mu\bar{G}(x-y)-\kappa}\}$ by applying the bisection method.

INT ; compute the constant $\gamma^{\#}$ such that ;

$\gamma^{\#} = \int_0^x F(dy)\frac{\lambda}{[\lambda+\mu\bar{G}(x-y)-\kappa]^2}$

by substituting the κ found in SK.

The following cases were simulated.

distribution	case	λ	$\mu(c)$	F(x)	G(x)
a, exponential	1,	1	1	$1-e^{-x}$	$1-e^{-x}$
(a=b=1)	2,	1	2	"	"
	3,	2	1	"	"
b, exponential	1,	1	1	$1-e^{-2x}$	$1-e^{-2x}$
(a=2, b=1)	2,	1	2	"	"
	3,	2	1	"	"
c, exponential	1,	1	$1/c$	$1-e^{-x}$	$1-e^{-x}$
with varying	2,	1	e^{-c}	"	"
arrival rate	3,	1	e^{c}	"	"
d, Pareto case	1,	1	2	$1-\frac{1}{1+x}$	$1-e^{-x}$
	2,	1	2	$1-\frac{1}{(1+x)^2}$	$1-e^{-x}$
	3,	1	2	$1-\frac{1}{1+x}$	$1-\frac{1}{1+x}$

These different settings will be referred to as case (A-1), (A-2), (A-3), (B-1), (B-2), (B-3), (C-1), (C-2), (C-3), (D-1), (D-2), (D-3) respectively throughout this paper. For each above case, we compare the asymptotic result (2-8) and the experimental results.

The next setting is to examine the exponential approximation of the tail of the distribution of T_x for finite x. The cases of identical exponential distributions, $\overline{F}(x)=\overline{G}(x)= e^{-x}$ and different exponential distributions,

$\overline{F}(x)=e^{-ax}$ $\overline{G}(x)=e^{-bx}$ where $a/b=2$

were considered.

The following conditions are considered.

e, $\lambda=\mu=1$ $\overline{F}(x)=\overline{G}(x)=e^{-x}$

f, $\lambda=\mu=1$ $\overline{F}(x)=e^{-2x}$, $\overline{G}(x)=e^{-x}$

These different settings will be referred to as case (E) and case (F) respectively. For each case, compute the κ, and constant γ^* and compare the quantiles of the asymptotic results (2-24) to the simulated data for each level of x.

IV. ANALYSIS OF THE SIMULATION RESULTS

As indicated in chapter 2 the exact distribution of T_x is difficult to obtain in general. In this chapter simulation will be used to study the accuracy of the approximations of the distribution of T_x by the exponential distributions suggested by the asymptotic results of chapter 2.

A. THE DISTRIBUTION OF T_x FOR INCREASING X

The limiting result (2-8) indicated that the distribution of T_x approaches the exponential as level x increases. This result suggests that the distribution of T_x can be approximated by an exponential distribution at least for large x. In this section this exponential approximation will be studied via a simulation.

1. Constant and Shock Load Magnitudes Have Identical Exponential Distributions

In the first collection of three models to be considered $\bar{F}(x)=\bar{G}(x)=e^{-x}$. The times between constant load changes are exponential with parameter λ and the shock load arrival rate μ is a constant independent of the constant load process.

For these cases it is possible to derive an analytical expression for $E(T_x)$.

$$\bar{F}(T_x)=\frac{e^x}{\lambda^2}\left[\frac{\lambda(1-e^{-x})-\mu x e^{-x}+\mu e^{-x}\ln\left(\frac{\lambda+\mu}{\lambda+\mu e^{-x}}\right)}{1+\frac{\mu}{\lambda}x-\frac{\mu}{\lambda}\ln\left(\frac{\lambda+\mu}{\lambda+\mu e^{-x}}\right)}\right] \qquad \text{-----------} (4-1)$$

In the Tables, $P(T_x=0)$ refers to the simulated sample probability that $T_x=0$; X-BAR gives the simulated

sample mean of T_x ; ST-DEV is the simulated standard deviation of T_x; VAR(X-B) is the variance of the sample mean; COEF-V is the sample standard deviation divided by the sample mean. T P($T_x=0$) is the theoretical probability that $T_x=0$, $\bar{F}(x)$; T x-bar is the theoretical mean of T_x computed from the equation (4-1).

The simulated coefficient of variation in all three cases decreases as the level x increases becoming quite close to the theoretical exponential value of 1 when x=5.

To compare the simulated distribution of T_x to the approximating exponential distribution, quantiles from the simulated data were computed and compared to the corresponding quantiles of an exponential distribution having theoretical mean (4-1). The simulated quantiles were computed as described in chapter 3. The exponential α-quantile is given by

$$q_\alpha = -a.\ln(1-\alpha)$$

where a is the mean of the exponential.

For each level of x, the first row in the tables (A.1), (A.2), (A.3) for the quantiles of the distribution of T_x gives the quantiles of the simulated data and the second row gives the corresponding exponential quantiles for an exponential distribution having theoretical mean (4-1).

One way the distribution of T_x differs from an exponential is that it has an atom at 0. In particular,

$$P(T_x=0)=\bar{F}(x)=e^{-x}$$

for the case considered here.

Quantiles were used to compare the simulated conditional distribution of T_x given $T_x>0$ to an exponential distribution having mean $E(T_x)/P(T_x>0)$. The simulated quantiles for the conditional distribution were computed as described in chapter 3. These quantiles were compared to those of an exponential distribution having theoretical mean $E(T_x)/P(T_x>0)$.

In the tables (A.1), (A.2), and (A.3) for the quantiles of the conditional distribution for each level x, the first row shows the simulated quantile and the second row the corresponding approximating exponential quantile.

The quantiles of the simulated conditional distribution are much closer to their exponential approximation than the quantiles for the unconditional distribution to their exponential approximation. However the quantiles for the unconditional distribution get closer to those of their approximating exponential as x increases.

Comparing tables (A.1), (A.2), and (A.3), it appears that increasing the arrival rate of shock or the rate of change of the constant load magnitude decreases the quantiles. The change of arrival rate of shocks appears to have the greater effect.

2. Constant and Shock Load Magnitudes Have Different Exponential Distributions

In the next three cases, the distribution of the shock load magnitudes is exponential with parameter 1 and the distribution of the constant load magnitudes is exponential with mean 0.5. The other model assumptions in tables (B.1), (B.2), (B.3) correspond to those in tables (A.1), (A.2), and (A.3).

As before, for each level x, the first row in the quantile table gives the simulated quantile and the second row gives the approximating exponential quantile using the exponential distribution with theoretical mean. Comparing the quantiles of T_x in table (B.1) with (A.1) (respectively (B.2) with (A.2) and (B.3) with (A.3)), it is seen that decreasing the mean constant load magnitudes has increased the quantiles. Further, it appears that the convergence of the distribution of T_x to an exponential is faster in the case of smaller mean constant load magnitude.

The exponential approximation to the conditional distribution of T_x given $T_x > 0$ has theoretical mean $E(T_x)/P(T_x > 0)$. Once again for small levels x, it appears that the exponential approximation to the conditional distribution of T_x is better than that for the unconditional one.

3. Arrival Rate of Shock Loads Depends on the Constant Load Magnitude

In the next 3 cases, constant load magnitudes and shock load magnitudes are exponential with mean 1. Constant load magnitudes change according to a Poisson process with rate 1. Given the constant load magnitude at time t is C, the probability a shock load will arrive in the time interval $[t, t+h]$ is $\mu(C)h + o(h)$.

In case (C-1) the conditional shock load arrival rate is $\mu(c)^{-1} = C$. Comparison with table (A.1) indicates that conditional shock arrival rate $\mu(c)^{-1} = C$ has the effect of decreasing the quantiles of T_x. Further the exponential approximation to the quantiles of T_x is not as good as in case (A-1).

The approximating exponential distribution to the conditional distribution of T_x given $T_x > 0$ has a mean of $E(T_x)/P(T_x > 0)$. The quantiles of the exponential approximation to the quantiles of the conditional distribution appear to be closer than those for the unconditional distribution.

In case (C-2) shock loads arrive with conditional arrival rate $\mu(C)^{-1} = \exp(C)$. Comparing the table (C.1) and (C.2), it is seen that the quantiles of the case $\mu(C)^{-1} = C$ are less than those for the case $\mu(C)^{-1} = \exp(C)$. This is because interarrival times tends to be larger for the case $\mu(C)^{-1} = \exp(C)$. Comparing tables (A.1) and (C.2) indicates that the exponential approximation to the quantiles of T_x is not as good as in the case $\mu = 1$.

In case (C-3) the conditional shock arrival rate is $\mu(C)^{-1} = \exp(-C)$. Comparing tables (C.2) and (C.3) indicates that the quantiles for the case $\mu(C)^{-1} = \exp(-C)$ are less than those for the case $\mu(C)^{-1} = \exp(C)$ and furthermore the exponential approximation of T_x appears to be close for the case (C-3) than that of for the case (C-2). In all of the cases the simulated mean was used as the parameter in the exponential approximations.

4. Load Magnitudes Have a Pareto Distribution

In the next three cases, the times between constant load changes of magnitude are exponential with mean 1. Shock loads arrive according to a Poisson process with rate 2. In case (D-1) the constant load magnitudes have a Pareto distribution with parameter $\alpha=1$ and the shock load magnitudes are exponentially distributed with mean 1. Comparison with table (A.2) indicates that the Pareto constant load magnitude has the effect of decreasing the quantiles of T_x. Further the exponential approximation to the quantiles of T_x is not good in the Pareto case; (the approximating exponential has a mean of the simulated sample mean).

The approximating exponential distribution of T_x given $T_x > 0$ to the conditional distribution has a mean of $E(T_x)/P(T_x > 0)$. Once again the quantiles of exponential approximation to the quantiles of the conditional distribution appear to be closer than those for the unconditional distribution.

In case (D-2) the constant load magnitudes have a Pareto distribution with parameter $\alpha=2$. Comparing tables (D.1) and (D.2) it is seen that the quantiles of the simulated distribution of T_x for the case $\alpha=2$ are larger than those for the case $\alpha=1$. Comparing tables (D.2) and (A.2) indicate that the exponential approximation to the quantiles of T_x is not as good for the Pareto case as for the exponential case.

In case (D-3) the constant load magnitudes have Pareto distribution with parameter $\alpha=1$ and the shock load magnitudes have Pareto distribution with $\alpha=1$. In all three cases the simulated mean was used in the approximating quantiles.

B. THE EXPONENTIAL TAIL OF THE DISTRIBUTION OF T_X FOR FINITE X

In this section simulation will be used to study the exponential approximation suggested by the asymptotic result

$$\lim_{t\to\infty} \frac{P(T_X>t)}{e^{\kappa t}} = \frac{1}{\gamma^{\#}}.$$

This is an approximation for $P(T_X>t)$ for fixed finite x; it should become more accurate as t becomes large.

Two cases are considered. In both cases shock loads arrive according to a Poisson process with rate 1 and constant load magnitudes change at the times of arrival of a Poisson process with rate 1. The shock load magnitudes have exponential distribution with mean 1. In case (E), the constant load magnitude distribution is exponential with mean 1; In case (F) it is exponential with mean 0.5.

Description of the computation of κ and $\gamma^{\#}$ for these two cases can be found in chapters 2,3. It can be seen from the computed value of $\kappa(x)$ and $\gamma^{\#}(x)$ appearing in tables, (E.1) and (F.1) that $\kappa(x)$ is approaching the value $1/E(T_X)$ (where $E(T_X)$ is the theoretical mean) as x becomes larger and for the cases computed $\kappa(x) \le \frac{1}{E(T_X)}$. Further, $\gamma^{\#}(x)$ is approaching 1 as x becomes larger.

To study the exponential approximation to the distribution of T, quantiles from the simulated data were computed. These can be found in tables (E.2) and (F.2). For each level x, the first row presents the simulated quantile; the second row gives the approximating α-quantile computed by

$$t_\alpha = \frac{1}{\kappa(x)}[-\ln[\gamma^{\#}(1-\alpha)]] \qquad \text{-------------------------- (I)}$$

The third row shows the approximating α-quantile computed by

$$q_\alpha = -E(T_x)\ln(1-\alpha) \quad \text{------------------------------} (\text{II})$$

where the theoretical mean is used for $E(T_x)$.

Comparing the quantiles in tables (E.2) and (F.2) it can be seen that the approximating quantiles (I) are close to the simulated ones even for $\alpha \approx .40$. The approximating quantiles computed in (II) do less well but improve as x becomes larger. The two approximating quantiles approach one another as x becomes larger, as expected. Approximating quantile (II) has the advantage, however, of being easier to compute.

Table (G.1) presents 90 % confidence intervals for α-quantiles with $\alpha \geq 0.9$ for case (E). These confidence intervals were computed using a large sample approximation, see Conover (1980; page 111-114) [Ref. 9].

Comparison with table (E.2) suggests that the approximating quantiles approximates the simulated ones well for these values.

C. CONCLUSIONS

Approximating quantile I is always better than approximating quantile II. Approximation I approximates q_α well for α as small as 0.40. However I is more difficult to compute than II.

The performance of approximating quantile II can be improved by changing it to

$$q_\alpha^{=} = -\frac{E(T_x)}{P(T_x>0)}\ln(1-\alpha)$$

and using it to approximate the quantiles of the conditional distribution of T_x given $T_x > 0$; for the models considered $P(T_x = 0)$ is easy to compute being equal to $\bar{F}(x)$.

TABLE A.1

Identical Exponential(case A-1)

X-LEV	P(TX=0)	T P(TX=0)	X-BAR	T X-BAR	ST-DEV	VAR(X-B)	COEF-V
0.50	0.6064	0.6065	0.2756	0.2871	0.5467	0.0001	1.9836
1.00	0.3562	0.3679	0.6666	0.6778	0.9704	0.0002	1.4514
1.50	0.2170	0.2231	1.2064	1.2316	1.5045	0.0005	1.2471
2.00	0.1350	0.1353	2.0003	2.0360	2.3536	0.0011	1.1766
2.50	0.0834	0.0821	3.1470	3.2216	3.4718	0.0024	1.1032
3.00	0.0504	0.0458	4.8776	4.9860	5.2666	0.0055	1.0798
3.50	0.0304	0.0302	7.4346	7.6314	7.7779	0.0121	1.0462
4.00	0.0184	0.0183	11.5392	11.6238	11.8121	0.0279	1.0237
4.50	0.0118	0.0111	17.5455	17.6335	17.7054	0.0627	1.0091
5.00	0.0064	0.0067	26.5447	26.9310	26.5839	0.1456	1.0015

** INPUT PARAMETERS **

CONSTANT ARRIVAL RATE = 1.00(POISSON)
CONSTANT-LOAD MAGNITUDE = 1.00(EXPONENTIAL)
SHOCK ARRIVAL RATE = 1.00(EXPONENTIAL)
SHOCK-LOAD MAGNITUDE = 1.00(EXPONENTIAL)

** QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.154	0.335	0.496	0.559	1.432	2.007	2.485
	0.020	0.064	0.083	0.102	0.147	0.199	0.263	0.346	0.398	0.462	0.661	0.860	1.123	1.322
1.00	0.0	0.0	0.0	0.0	0.070	0.261	0.453	0.751	0.972	1.200	1.518	2.683	3.631	4.358
	0.071	0.151	0.155	0.242	0.346	0.470	0.621	0.816	0.940	1.091	1.561	2.031	2.652	3.122
1.50	0.0	0.0	0.064	0.167	0.402	0.680	1.012	1.467	1.748	2.051	3.242	4.304	5.542	6.552
	0.130	0.275	0.354	0.439	0.629	0.854	1.129	1.463	1.707	1.982	2.836	3.690	4.618	5.672
2.00	0.0	0.171	0.313	0.454	0.820	1.233	1.746	2.420	2.877	3.393	5.111	6.450	8.675	10.419
	0.215	0.454	0.586	0.726	1.040	1.411	1.866	2.451	2.823	3.277	4.688	6.099	7.565	9.376
2.50	0.063	0.440	0.645	0.908	1.442	2.045	2.824	3.811	4.524	5.271	7.650	10.035	12.841	15.033
	0.335	0.719	0.927	1.149	1.646	2.233	2.952	3.879	4.466	5.185	7.418	9.651	12.603	14.836
3.00	0.252	0.847	1.164	1.525	2.255	3.175	4.364	5.923	6.916	8.059	11.497	15.012	20.501	24.655
	0.525	1.113	1.434	1.778	2.547	3.456	4.569	6.003	6.912	8.025	11.481	14.937	19.505	22.961
3.50	0.560	1.438	1.884	2.343	3.450	4.997	6.808	9.019	10.341	12.098	17.663	28.250	29.161	34.790
	0.804	1.703	2.195	2.722	3.858	5.290	6.953	9.168	10.579	12.282	17.572	22.862	25.854	35.144
4.00	0.950	2.229	2.949	3.726	5.702	7.562	10.540	13.958	16.339	18.902	26.659	34.861	47.156	54.212
	1.225	2.594	3.344	4.146	5.938	8.057	10.651	13.955	16.114	18.708	26.765	34.822	45.473	53.530
4.50	1.612	3.605	4.937	6.226	8.920	12.156	16.316	21.302	24.428	27.967	40.431	53.411	69.612	82.686
	1.863	3.946	5.087	6.307	9.033	12.258	16.204	21.251	24.515	28.461	40.719	52.976	65.160	81.437
5.00	2.404	5.738	7.584	9.387	13.661	18.508	24.480	32.219	37.717	44.380	62.579	81.667	105.922	123.817
	2.637	6.009	7.748	9.606	13.757	18.66[illegible]	24.677	32.424	37.334	43.344	62.011	80.678	105.355	124.022

** CONDITIONAL QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.075	0.159	0.207	0.264	0.374	0.505	0.669	0.852	0.966	1.120	1.590	2.007	2.621	3.072
	0.074	0.156	0.201	0.250	0.358	0.485	0.642	0.843	0.971	1.127	1.612	2.098	2.739	3.225
1.00	0.112	0.238	0.255	0.373	0.534	0.727	0.940	1.245	1.445	1.667	2.384	3.117	4.205	4.859
	0.110	0.232	0.300	0.372	0.532	0.722	0.955	1.254	1.444	1.677	2.399	3.121	4.075	4.797
1.50	0.156	0.339	0.430	0.543	0.780	1.045	1.409	1.837	2.133	2.502	3.596	4.650	5.670	7.017
	0.162	0.344	0.443	0.550	0.787	1.068	1.412	1.855	2.136	2.480	3.548	4.616	6.028	7.096
2.00	0.231	0.481	0.628	0.796	1.143	1.575	2.079	2.784	3.203	3.705	5.353	6.927	9.239	10.737
	0.244	0.516	0.665	0.825	1.181	1.603	2.119	2.784	3.206	3.722	5.325	6.927	9.046	10.649
2.50	0.356	0.748	0.964	1.191	1.728	2.356	3.131	4.149	4.839	5.541	7.937	10.273	13.142	15.703
	0.362	0.766	0.988	1.225	1.754	2.380	3.146	4.134	4.760	5.526	7.906	10.286	13.432	15.811
3.00	0.510	1.094	1.442	1.783	2.521	3.435	4.677	6.213	7.218	8.306	11.763	15.419	20.761	24.913
	0.541	1.146	1.478	1.832	2.624	3.560	4.707	6.184	7.121	8.267	11.827	15.388	20.054	23.654
3.50	0.753	1.673	2.059	2.561	3.724	5.237	7.055	9.214	10.644	12.323	18.016	23.374	29.495	35.110
	0.808	1.711	2.206	2.735	3.917	5.315	7.026	9.222	10.630	12.341	17.655	22.970	29.996	35.311
4.00	1.187	2.404	3.172	3.957	5.926	8.126	10.769	14.276	16.575	19.076	26.773	35.131	47.471	54.212
	1.239	2.623	3.382	4.153	6.005	8.148	10.771	14.153	16.297	18.920	27.068	35.216	45.988	54.136
4.50	1.807	3.835	5.178	6.451	9.137	12.388	16.479	21.464	24.604	28.141	40.690	53.713	65.617	82.686
	1.871	3.962	5.108	6.333	9.070	12.307	16.269	21.377	24.614	28.576	40.882	53.189	69.458	81.765
5.00	2.523	5.877	7.775	9.552	13.824	18.691	24.638	32.374	37.877	44.527	63.174	81.777	105.922	123.817
	2.657	6.051	7.601	9.672	13.853	18.797	24.848	32.650	37.594	43.645	62.442	81.239	106.087	124.884

TABLE A.2

Identical Exponential(case A-2)

X-LEV	P(TX=0)	T P(TX=0)	X-BAR	T X-BAR	ST-DEV	VAR(X-B)	COEF-V
0.50	0.6208	0.6065	0.1755	0.1848	0.3727	0.0000	2.0765
1.00	0.3710	0.3679	0.4257	0.4264	0.6420	0.0001	1.4939
1.50	0.2256	0.2231	0.7555	0.7639	0.9565	0.0002	1.2594
2.00	0.1382	0.1353	1.2382	1.2515	1.4638	0.0004	1.1823
2.50	0.0804	0.0821	1.5408	1.9664	2.1480	0.0009	1.1068
3.00	0.0506	0.0498	2.9616	3.0230	3.2211	0.0021	1.0876
3.50	0.0256	0.0302	4.4757	4.5938	4.6683	0.0044	1.0421
4.00	0.0166	0.0183	6.5136	6.9419	7.1564	0.0102	1.0351
4.50	0.0094	0.0111	10.5252	10.4719	10.7015	0.0225	1.0168
5.00	0.0058	0.0067	16.0074	15.8087	16.3672	0.0536	1.0225

** INPUT PARAMETERS **

CONSTANT ARRIVAL RATE = 1.00(POISSON)
CONSTANT-LOAD MAGNITUDE = 1.00(EXPONENTIAL)
SHOCK ARRIVAL RATE = 2.00(EXPONENTIAL)
SHOCK-LOAD MAGNITUDE = 1.00(EXPONENTIAL)

** QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.115	0.200	0.304	0.428	0.548	1.347	1.674
	0.015	0.041	0.053	0.066	0.094	0.128	0.169	0.223	0.256	0.297	0.426	0.554	0.723	0.851
1.00	0.0	0.0	0.0	0.0	0.034	0.149	0.201	0.493	0.620	0.788	1.266	1.719	2.386	2.917
	0.045	0.095	0.123	0.152	0.218	0.296	0.351	0.513	0.591	0.686	0.982	1.277	1.668	1.964
1.50	0.0	0.0	0.032	0.055	0.245	0.425	0.621	0.934	1.127	1.340	2.008	2.683	3.605	4.314
	0.060	0.170	0.220	0.272	0.350	0.530	0.700	0.920	1.059	1.230	1.759	2.289	2.989	3.518
2.00	0.0	0.102	0.186	0.250	0.457	0.761	1.055	1.525	1.776	2.085	3.069	4.100	5.563	6.608
	0.132	0.279	0.360	0.446	0.639	0.867	1.147	1.507	1.735	2.014	2.882	3.149	4.656	5.763
2.50	0.043	0.280	0.411	0.532	0.879	1.288	1.755	2.359	2.730	3.196	4.724	6.221	8.262	10.202
	0.207	0.439	0.566	0.701	1.005	1.363	1.802	2.368	2.726	3.165	4.528	5.891	7.653	9.056
3.00	0.150	0.499	0.687	0.912	1.428	1.960	2.665	3.538	4.073	4.828	7.020	9.243	11.359	14.757
	0.215	0.675	0.870	1.078	1.544	2.095	2.770	3.640	4.191	4.865	6.961	9.056	11.826	13.922
3.50	0.334	0.881	1.151	1.534	2.183	2.979	4.005	5.402	6.304	7.330	10.618	13.605	17.763	21.551
	0.464	1.025	1.322	1.638	2.347	3.184	4.209	5.531	6.368	7.393	10.578	13.762	17.971	21.155
4.00	0.583	1.441	1.843	2.312	3.351	4.610	6.328	8.344	9.603	11.259	15.883	21.359	28.557	33.030
	0.731	1.549	1.997	2.476	3.546	4.812	6.361	8.358	9.623	11.172	15.984	20.796	27.157	31.968
4.50	0.947	2.150	2.834	3.562	5.341	7.290	9.828	12.822	14.647	16.808	24.622	32.307	41.067	47.527
	1.103	2.337	3.013	3.735	5.349	7.259	9.555	12.608	14.517	16.854	24.113	31.371	40.566	48.225
5.00	1.562	3.349	4.291	5.657	8.142	11.031	14.458	18.874	21.904	26.379	37.182	48.043	62.333	72.882
	1.666	3.528	4.548	5.639	8.075	10.958	14.485	19.033	21.915	25.443	36.401	47.359	61.844	72.802

** CONDITIONAL QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.057	0.111	0.137	0.170	0.239	0.329	0.437	0.560	0.654	0.758	1.072	1.384	1.653	2.156
	0.050	0.106	0.136	0.169	0.242	0.328	0.434	0.570	0.656	0.762	1.090	1.418	1.651	2.180
1.00	0.073	0.145	0.193	0.236	0.338	0.462	0.614	0.821	0.946	1.113	1.571	2.008	2.722	3.297
	0.072	0.152	0.197	0.244	0.349	0.474	0.626	0.823	0.947	1.100	1.573	2.047	2.673	3.146
1.50	0.098	0.212	0.276	0.342	0.489	0.663	0.906	1.202	1.369	1.585	2.262	2.518	3.864	4.614
	0.103	0.219	0.282	0.350	0.501	0.680	0.899	1.181	1.360	1.578	2.258	2.938	3.827	4.516
2.00	0.143	0.312	0.396	0.489	0.702	0.973	1.320	1.728	1.966	2.300	3.297	4.366	5.695	6.704
	0.151	0.321	0.413	0.512	0.734	0.996	1.316	1.730	1.992	2.312	3.308	4.304	5.620	6.016
2.50	0.208	0.442	0.561	0.714	1.056	1.475	1.931	2.533	2.903	3.350	4.906	6.396	8.550	10.320
	0.222	0.471	0.607	0.753	1.078	1.463	1.934	2.541	2.926	3.357	4.859	6.322	8.256	9.719
3.00	0.305	0.640	0.856	1.082	1.589	2.111	2.805	3.725	4.208	5.015	7.165	9.292	12.573	15.152
	0.325	0.696	0.897	1.113	1.553	2.162	2.858	3.755	4.324	5.021	7.183	9.345	12.203	14.366
3.50	0.468	1.024	1.345	1.642	2.302	3.137	4.110	5.561	6.437	7.466	10.768	13.734	17.863	21.582
	0.466	1.030	1.328	1.647	2.358	3.200	4.230	5.558	6.400	7.430	10.630	13.629	18.059	21.259
4.00	0.702	1.563	1.981	2.450	3.465	4.719	6.445	8.433	9.695	11.385	15.996	21.551	28.559	33.030
	0.741	1.509	2.022	2.508	3.591	4.873	6.442	8.464	9.740	11.315	16.188	21.061	27.503	32.376
4.50	1.035	2.228	2.921	3.468	5.409	7.384	9.946	12.922	14.733	17.001	24.714	32.411	41.067	47.527
	1.119	2.371	3.057	3.790	5.428	7.365	9.736	12.792	14.730	17.100	24.465	31.630	41.566	48.930
5.00	1.635	3.441	4.509	5.802	8.228	11.157	14.552	18.986	22.019	26.409	37.266	48.159	62.333	72.882
	1.656	3.593	4.632	5.743	8.225	11.160	14.753	19.385	22.320	25.913	37.073	48.233	62.966	74.147

TABLE A.3

Identical Exponential(case A-3)

X-LEV	P(TX=0)	T P(TX=0)	X-BAR	T X-BAR	ST-DEV	VAR(X-B)	COEF-V
0.50	0.6068	0.6065	0.2020	0.1988	0.4100	0.0000	2.0295
1.00	0.3518	0.3679	0.5004	0.4837	0.7299	0.0001	1.4586
1.50	0.2104	0.2231	0.5134	0.9004	1.1294	0.0003	1.2364
2.00	0.1266	0.1353	1.5451	1.5189	1.7564	0.0006	1.1338
2.50	0.0782	0.0821	2.4630	2.4464	2.7194	0.0015	1.0952
3.00	0.0440	0.0458	3.5210	3.8463	4.0685	0.0033	1.0376
3.50	0.0286	0.0302	6.0263	5.9811	6.0863	0.0074	1.0099
4.00	0.0182	0.0163	9.2779	9.2433	9.5375	0.0182	1.0280
4.50	0.0112	0.0111	14.1536	14.2567	14.4093	0.0415	1.0181
5.00	0.0072	0.0067	21.8165	21.9940	22.1620	0.0982	1.0130

** INPUT PARAMETERS **

CONSTANT ARRIVAL RATE = 2.00(POISSON)
CONSTANT-LOAD MAGNITUDE = 1.00(EXPONENTIAL)
SHOCK ARRIVAL RATE = 1.00(EXPONENTIAL)
SHOCK-LOAD MAGNITUDE = 1.00(EXPONENTIAL)

** QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.139	0.233	0.344	0.685	1.058	1.577	1.885
	0.021	0.044	0.057	0.071	0.102	0.138	0.182	0.239	0.276	0.320	0.458	0.596	0.778	0.915
1.00	0.0	0.0	0.0	0.0	0.060	0.202	0.350	0.568	0.736	0.858	1.417	1.912	2.642	3.357
	0.051	0.108	0.139	0.173	0.247	0.335	0.443	0.562	0.671	0.778	1.114	1.449	1.852	2.227
1.50	0.0	0.0	0.057	0.131	0.306	0.522	0.773	1.117	1.343	1.594	2.428	3.221	4.155	5.054
	0.055	0.201	0.259	0.321	0.460	0.624	0.825	1.084	1.248	1.449	2.073	2.657	3.522	4.146
2.00	0.0	0.153	0.271	0.353	0.649	0.972	1.380	1.856	2.254	2.657	3.657	5.165	6.560	7.767
	0.160	0.339	0.437	0.542	0.776	1.053	1.392	1.829	2.106	2.445	3.497	4.550	5.942	6.995
2.50	0.067	0.375	0.528	0.714	1.110	1.620	2.255	3.038	3.494	4.125	6.131	7.826	10.186	12.001
	0.258	0.546	0.704	0.873	1.250	1.696	2.242	2.945	3.391	3.937	5.633	7.329	9.570	11.266
3.00	0.261	0.721	0.961	1.249	1.898	2.670	3.575	4.824	5.570	6.541	9.217	12.078	15.508	18.520
	0.405	0.859	1.107	1.373	1.966	2.667	3.526	4.633	5.335	6.194	8.861	11.529	15.055	17.722
3.50	0.477	1.216	1.643	2.073	3.101	4.177	5.541	7.309	8.406	9.813	14.207	17.949	23.466	27.905
	0.630	1.335	1.721	2.133	3.055	4.146	5.460	7.201	8.292	9.626	13.772	17.918	23.358	27.544
4.00	0.806	1.928	2.609	3.250	4.626	6.363	8.317	11.018	12.841	14.952	21.512	28.196	38.172	43.673
	0.974	2.063	2.659	3.297	4.722	6.407	8.470	11.129	12.814	14.877	21.284	27.690	36.160	42.567
4.50	1.354	3.110	3.967	4.872	7.113	9.544	12.884	16.928	19.762	22.543	33.011	42.918	56.946	65.090
	1.502	3.181	4.101	5.065	7.283	9.882	13.063	17.165	19.764	22.945	32.827	42.709	55.773	65.655
5.00	2.135	4.652	6.077	7.542	11.060	15.094	20.311	26.136	30.021	34.619	50.846	66.911	88.753	101.143
	2.317	4.908	6.327	7.845	11.235	15.245	20.153	26.460	30.490	35.398	50.643	65.868	86.041	101.286

** CONDITIONAL QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.056	0.112	0.154	0.188	0.263	0.350	0.470	0.608	0.695	0.805	1.153	1.578	1.966	2.382
	0.054	0.115	0.148	0.183	0.262	0.356	0.471	0.619	0.712	0.827	1.183	1.539	2.010	2.366
1.00	0.064	0.172	0.221	0.278	0.407	0.532	0.705	0.916	1.070	1.239	1.736	2.260	3.088	3.675
	0.081	0.172	0.222	0.275	0.394	0.535	0.707	0.930	1.070	1.243	1.778	2.313	3.020	3.555
1.50	0.113	0.254	0.326	0.411	0.580	0.793	1.060	1.407	1.607	1.862	2.676	3.501	4.467	5.339
	0.122	0.258	0.333	0.413	0.591	0.802	1.060	1.393	1.604	1.862	2.664	3.466	4.526	5.327
2.00	0.185	0.394	0.494	0.613	0.888	1.198	1.622	2.152	2.507	2.915	4.058	5.333	6.750	8.023
	0.187	0.396	0.510	0.633	0.906	1.229	1.625	2.135	2.459	2.854	4.084	5.313	6.938	8.168
2.50	0.264	0.573	0.743	0.926	1.340	1.826	2.476	3.256	3.744	4.364	6.342	8.032	10.303	12.191
	0.264	0.601	0.775	0.961	1.376	1.867	2.468	3.243	3.734	4.335	6.202	8.070	10.538	12.405
3.00	0.440	0.889	1.148	1.454	2.085	2.866	3.772	5.019	5.771	6.714	9.326	12.245	15.778	18.777
	0.432	0.915	1.180	1.463	2.095	2.843	3.758	4.938	5.686	6.601	9.444	12.287	16.045	18.888
3.50	0.652	1.398	1.815	2.260	3.249	4.340	5.722	7.483	8.598	9.998	14.411	18.117	23.535	27.981
	0.654	1.384	1.785	2.213	3.169	4.300	5.684	7.469	8.600	9.985	14.285	18.585	24.269	28.569
4.00	1.009	2.129	2.787	3.422	4.763	6.540	8.445	11.234	13.094	15.101	21.657	28.420	36.164	43.673
	0.996	2.109	2.719	3.371	4.827	6.550	8.659	11.377	13.100	15.209	21.759	28.309	36.968	43.518
4.50	1.565	3.226	4.113	5.036	7.271	9.722	13.113	17.058	19.904	22.770	33.265	43.278	56.564	65.090
	1.508	3.194	4.118	5.105	7.312	9.922	13.116	17.234	19.843	23.037	32.959	42.881	55.996	65.918
5.00	2.280	4.788	6.226	7.663	11.272	15.259	20.370	26.251	30.117	34.839	51.007	67.153	88.753	101.143
	2.322	4.917	6.339	7.860	11.256	15.274	20.191	26.530	30.548	35.465	50.739	66.013	86.264	101.478

TABLE B.1

Different Exponential(case B-1)

X-LEV	P(TX=0)	T P(TX=0)	X-BAR	T X-BAR	ST-DEV	VAR(X-B)	COEF-V
0.50	0.3634	0.3679	0.5766	0.5662	0.8377	0.0001	1.4529
1.00	0.1368	0.1353	1.3250	1.3117	1.5200	0.0005	1.1437
1.50	0.0512	0.0458	2.3610	2.3775	2.5240	0.0013	1.0601
2.00	0.0192	0.0183	3.5756	4.0042	4.1208	0.0034	1.0355
2.50	0.0066	0.0067	6.5556	6.5746	6.7545	0.0091	1.0297
3.00	0.0030	0.0025	10.5459	10.7070	10.5927	0.0224	1.0060
3.50	0.0012	0.0009	17.4387	17.4129	17.6387	0.0622	1.0116
4.00	0.0002	0.0003	28.0142	28.3556	27.9150	0.1558	0.9965
4.50	0.0002	0.0001	46.1649	46.2752	46.3970	0.4305	1.0046
5.00	0.0002	0.0000	75.4248	75.6930	75.6413	1.1443	1.0029

** INPUT PARAMETERS **

CONSTANT ARRIVAL RATE = 1.00(POISSON)
CONSTANT-LOAD MAGNITUDE = 2.00(EXPONENTIAL)
SHOCK ARRIVAL RATE = 1.00(EXPONENTIAL)
SHOCK-LOAD MAGNITUDE = 1.00(EXPONENTIAL)

** QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.0	0.0	0.0	0.0	0.059	0.232	0.437	0.671	0.843	1.048	1.660	2.281	3.082	3.856
	0.060	0.126	0.163	0.202	0.289	0.392	0.519	0.682	0.785	0.911	1.304	1.696	2.215	2.607
1.00	0.0	0.118	0.219	0.327	0.560	0.838	1.182	1.635	1.913	2.267	3.351	4.309	5.913	6.693
	0.138	0.293	0.377	0.468	0.670	0.909	1.202	1.579	1.818	2.111	3.020	3.930	5.132	6.041
1.50	0.128	0.408	0.570	0.756	1.147	1.615	2.204	2.915	3.348	3.886	5.702	7.392	9.602	11.935
	0.250	0.531	0.684	0.848	1.214	1.648	2.178	2.862	3.256	3.826	5.474	7.122	9.301	10.949
2.00	0.325	0.822	1.084	1.329	1.976	2.699	3.615	4.735	5.491	6.441	9.237	12.194	16.075	19.031
	0.422	0.894	1.152	1.428	2.045	2.775	3.669	4.821	5.551	6.444	9.220	11.995	15.664	18.440
2.50	0.621	1.398	1.626	2.251	3.273	4.372	5.858	7.943	9.028	10.415	15.258	20.490	27.017	31.391
	0.653	1.407	1.891	2.345	3.358	4.557	6.024	7.916	9.114	10.581	15.139	19.696	25.720	30.277
3.00	1.072	2.321	2.954	3.643	5.185	7.180	9.477	12.556	14.649	17.429	24.906	31.688	41.551	48.155
	1.126	2.389	3.080	3.819	5.469	7.422	9.811	12.851	14.843	17.232	24.654	32.075	41.866	49.308
3.50	1.712	3.752	4.847	6.073	8.927	12.005	15.532	20.921	24.129	28.173	39.746	52.594	70.963	82.554
	1.825	3.886	5.009	6.211	8.855	12.070	15.955	20.965	24.139	28.025	40.095	52.164	68.120	80.189
4.00	2.507	6.233	8.247	10.036	14.388	19.494	25.659	33.518	38.714	45.050	65.657	84.429	107.641	123.499
	2.988	6.327	8.157	10.114	14.485	19.655	25.982	34.139	39.309	45.037	65.291	84.946	110.928	130.582
4.50	4.665	10.343	13.413	16.627	23.411	31.860	41.704	55.498	64.297	74.944	107.006	137.965	183.010	221.111
	4.676	10.326	13.313	16.505	23.639	32.076	42.402	55.714	64.151	74.477	106.553	138.628	181.030	213.105
5.00	8.137	17.063	21.753	26.729	38.244	52.403	70.553	91.378	104.272	120.132	170.502	224.441	258.617	350.441
	7.975	16.890	21.776	26.998	38.666	52.466	69.357	91.122	104.933	121.823	174.250	226.756	256.113	348.579

** CONDITIONAL QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.058	0.212	0.275	0.336	0.477	0.629	0.827	1.087	1.255	1.436	2.019	2.711	3.546	4.232
	0.055	0.202	0.261	0.323	0.463	0.628	0.830	1.050	1.256	1.458	2.085	2.713	3.543	4.171
1.00	0.157	0.349	0.443	0.543	0.789	1.063	1.415	1.854	2.157	2.488	3.580	4.533	6.065	6.841
	0.162	0.344	0.443	0.549	0.786	1.067	1.411	1.854	2.134	2.478	3.545	4.612	6.023	7.090
1.50	0.254	0.534	0.707	0.886	1.278	1.741	2.336	3.044	3.483	4.012	5.816	7.625	9.830	12.005
	0.264	0.560	0.722	0.855	1.282	1.739	2.259	3.021	3.479	4.039	5.778	7.518	9.817	11.556
2.00	0.355	0.899	1.146	1.408	2.059	2.772	3.676	4.804	5.566	6.502	9.277	12.202	16.086	19.031
	0.428	0.905	1.167	1.447	2.073	2.812	3.718	4.865	5.625	6.530	9.343	12.155	15.673	18.686
2.50	0.613	1.448	1.870	2.331	3.315	4.420	5.918	7.986	9.062	10.443	15.386	20.542	27.017	31.391
	0.656	1.473	1.900	2.355	3.373	4.577	6.050	7.950	9.154	10.627	15.204	19.781	25.632	30.409
3.00	1.096	2.348	2.978	3.667	5.207	7.220	9.497	12.576	14.689	17.450	24.933	31.743	41.551	48.155
	1.113	2.357	3.038	3.767	5.355	7.321	9.677	12.716	14.641	16.998	24.319	31.640	41.317	48.638
3.50	1.738	3.777	4.861	6.095	8.964	12.024	15.947	20.921	24.160	28.180	39.746	52.628	70.963	82.554
	1.825	3.896	5.022	6.227	8.918	12.101	15.996	21.018	24.201	28.097	40.198	52.258	66.255	80.395
4.00	2.507	6.253	8.247	10.036	14.388	19.494	25.659	33.518	38.714	45.050	65.657	84.429	107.641	123.499
	2.952	6.252	8.061	9.994	14.313	19.422	25.674	33.735	38.844	45.096	64.518	83.940	105.614	129.036
4.50	4.685	10.343	13.413	16.627	23.411	31.860	41.704	55.498	64.297	74.944	107.006	137.965	183.010	221.111
	4.667	10.308	13.289	16.476	23.597	32.019	42.327	55.616	64.039	74.347	106.366	138.385	180.712	212.732
5.00	8.137	17.063	21.753	26.729	38.244	52.403	70.553	91.378	104.272	120.132	170.502	224.441	258.617	350.441
	7.548	16.834	21.703	26.908	38.537	52.291	69.125	90.627	104.582	121.416	173.707	225.998	255.122	347.413

TABLE B.2

Different Exponential(case B-2)

X-LEV	P(TX=0)	T P(TX=0)	X-BAR	T X-BAR	ST-DEV	VAR(X-B)	COEF-V
0.50	0.3614	0.3679	0.3376	0.3399	0.4868	0.0000	1.4417
1.00	0.1306	0.1353	0.7135	0.7384	0.8557	0.0001	1.1357
1.50	0.0460	0.0498	1.2551	1.2919	1.3758	0.0004	1.0590
2.00	0.0212	0.0183	2.1452	2.1326	2.2104	0.0010	1.0285
2.50	0.0068	0.0067	3.4441	3.4565	3.4999	0.0024	1.0162
3.00	0.0028	0.0025	5.6352	5.5735	5.7916	0.0067	1.0270
3.50	0.0008	0.0009	9.1512	8.9892	9.2692	0.0172	1.0085
4.00	0.0	0.0003	14.5575	14.5344	14.5369	0.0423	0.9958
4.50	0.0	0.0001	23.3353	23.5784	23.2725	0.1083	0.9971
5.00	0.0	0.0000	37.6659	38.3794	37.8526	0.2866	1.0049

** INPUT PARAMETERS **

CONSTANT ARRIVAL RATE = 1.00(POISSON)
CONSTANT-LOAD MAGNITUDE = 2.00(EXPONENTIAL)
SHOCK ARRIVAL RATE = 2.0C(EXPONENTIAL)
SHOCK-LOAD MAGNITUDE = 1.CC(EXPONENTIAL)

** QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.0	0.0	0.0	0.0	0.032	0.129	0.248	0.411	0.504	0.617	0.579	1.344	1.625	2.182
	0.026	0.076	0.098	0.121	0.174	0.236	0.311	0.409	0.471	0.547	0.783	1.018	1.330	1.565
1.00	0.0	0.072	0.127	0.166	0.312	0.477	0.669	0.920	1.086	1.286	1.510	2.477	3.151	3.780
	0.078	0.165	0.212	0.263	0.377	0.512	0.677	0.869	1.024	1.188	1.700	2.212	2.669	3.401
1.50	0.075	0.232	0.317	0.419	0.627	0.872	1.188	1.560	1.823	2.127	3.065	4.071	5.261	6.361
	0.136	0.288	0.372	0.461	0.660	0.895	1.184	1.555	1.791	2.079	2.575	3.870	5.054	5.949
2.00	0.176	0.431	0.572	0.722	1.076	1.469	1.560	2.574	2.965	3.470	5.071	6.566	8.717	10.225
	0.225	0.476	0.614	0.761	1.089	1.478	1.954	2.568	2.956	3.432	4.511	6.389	8.343	9.821
2.50	0.343	0.728	0.948	1.202	1.744	2.333	3.108	4.127	4.793	5.614	8.055	10.515	13.418	15.612
	0.364	0.771	0.994	1.233	1.766	2.396	3.167	4.162	4.792	5.563	7.559	10.355	13.522	15.918
3.00	0.573	1.241	1.598	1.962	2.782	3.839	5.080	6.693	7.773	9.064	12.923	17.145	23.340	27.160
	0.567	1.244	1.603	1.968	2.847	3.863	5.107	6.710	7.727	8.970	12.833	16.697	21.804	25.607
3.50	0.927	1.972	2.507	3.221	4.645	6.389	8.487	11.342	12.759	14.838	21.181	27.372	35.792	41.948
	0.547	2.006	2.586	3.206	4.592	6.231	8.237	10.823	12.462	14.468	20.698	26.929	35.166	41.397
4.00	1.515	3.275	4.271	5.409	7.580	10.231	13.475	17.337	19.696	23.011	33.620	44.433	57.043	65.996
	1.531	3.243	4.181	5.164	7.425	10.074	13.318	17.459	20.149	23.392	33.407	43.541	56.859	66.933
4.50	2.400	5.552	6.974	8.612	12.035	16.084	21.269	28.076	32.430	37.026	53.622	69.457	93.834	109.742
	2.464	5.261	6.783	8.410	12.044	16.343	21.605	28.368	32.667	37.948	54.291	70.634	92.239	108.582
5.00	4.069	8.186	10.707	13.172	18.561	25.699	34.300	45.119	51.871	60.724	88.753	115.873	146.702	168.095
	4.044	8.564	11.041	13.669	19.605	26.603	35.167	46.208	53.205	61.769	88.372	114.974	150.141	176.744

** CONDITIONAL QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.056	0.118	0.148	0.188	0.274	0.377	0.492	0.641	0.737	0.853	1.216	1.546	2.008	2.390
	0.055	0.118	0.152	0.189	0.270	0.366	0.484	0.637	0.733	0.851	1.217	1.584	2.068	2.435
1.00	0.051	0.191	0.245	0.301	0.436	0.592	0.762	1.045	1.194	1.411	2.047	2.590	3.267	3.885
	0.051	0.193	0.249	0.309	0.443	0.601	0.794	1.043	1.201	1.395	1.596	2.596	3.390	3.991
1.50	0.143	0.297	0.391	0.461	0.657	0.948	1.243	1.654	1.887	2.186	3.106	4.140	5.325	6.371
	0.144	0.305	0.393	0.467	0.697	0.946	1.250	1.643	1.892	2.196	3.142	4.088	5.339	6.284
2.00	0.221	0.479	0.619	0.764	1.121	1.532	1.998	2.628	3.016	3.533	5.109	6.613	6.728	10.342
	0.231	0.490	0.632	0.783	1.122	1.522	2.012	2.644	3.044	3.534	5.056	6.578	8.550	10.112
2.50	0.367	0.753	0.970	1.221	1.764	2.354	3.130	4.157	4.815	5.629	8.064	10.524	13.418	15.612
	0.365	0.774	0.998	1.237	1.771	2.404	3.177	4.175	4.807	5.581	7.585	10.388	13.565	15.969
3.00	0.565	1.254	1.602	1.974	2.788	3.854	5.065	6.702	7.778	9.078	12.955	17.159	23.340	27.160
	0.556	1.262	1.627	2.017	2.889	3.920	5.182	6.868	7.839	9.101	13.021	16.541	22.122	26.042
3.50	0.528	1.974	2.509	3.242	4.647	6.394	8.492	11.342	12.759	14.838	21.181	27.402	35.792	41.948
	0.565	2.053	2.646	3.261	4.659	6.376	8.429	11.075	12.752	14.604	21.180	27.556	35.965	42.361
4.00	1.515	3.275	4.271	5.409	7.580	10.231	13.475	17.337	19.696	23.011	33.620	44.433	57.043	65.996
	1.538	3.257	4.199	5.207	7.457	10.118	13.376	17.575	20.236	23.494	33.612	43.730	57.106	67.224
4.50	2.400	5.552	6.974	8.612	12.035	16.084	21.269	28.076	32.430	37.026	53.622	69.457	93.834	109.742
	2.459	5.208	6.714	8.323	11.922	16.178	21.366	28.100	32.355	37.563	53.741	69.518	91.304	107.482
5.00	4.069	8.186	10.707	13.172	18.561	25.699	34.300	45.119	51.871	60.724	88.753	115.873	148.702	168.095
	3.569	8.406	10.637	13.436	19.243	26.111	34.517	45.354	52.222	60.627	86.738	112.849	147.365	173.476

TABLE B.3

Different Exponential(case B-3)

X-LEV	P(TX=0)	T P(TX=0)	X-BAR	T X-BAR	ST-DEV	VAR(X-B)	COEF-V
0.50	0.3644	0.3679	0.4203	0.4252	0.6160	0.0001	1.4655
1.00	0.1334	0.1353	1.0745	1.0812	1.2598	0.0003	1.1720
1.50	0.0468	0.0458	2.0602	2.0873	2.1069	0.0010	1.0513
2.00	0.0166	0.0183	3.6055	3.6620	3.7385	0.0028	1.0357
2.50	0.0062	0.0067	6.1555	6.1761	6.2788	0.0075	1.0200
3.00	0.0026	0.0025	10.1050	10.2431	10.4621	0.0219	1.0349
3.50	0.0012	0.0009	16.4715	16.6733	16.3493	0.0535	0.9926
4.00	0.0004	0.0003	27.2115	27.7254	27.4873	0.1511	1.0101
4.50	0.0002	0.0001	44.9755	45.5566	44.5880	0.4048	1.0002
5.00	0.0	0.0000	75.3058	74.8736	78.3367	1.2273	1.0402

** INPUT PARAMETERS **

CONSTANT ARRIVAL RATE = 2.00(POISSON)
CONSTANT-LOAD MAGNITUDE = 2.00(EXPONENTIAL)
SHOCK ARRIVAL RATE = 1.00(EXPONENTIAL)
SHOCK-LOAD MAGNITUDE = 1.00(EXPONENTIAL)

** QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.0	0.0	0.0	0.0	0.041	0.164	0.303	0.454	0.622	0.755	1.223	1.668	2.282	2.839
	0.045	0.095	0.122	0.152	0.217	0.295	0.350	0.512	0.569	0.684	0.979	1.274	1.663	1.958
1.00	0.0	0.102	0.177	0.255	0.443	0.677	0.959	1.267	1.487	1.775	2.725	3.642	4.764	5.604
	0.114	0.241	0.311	0.386	0.552	0.749	0.991	1.302	1.499	1.740	2.489	3.239	4.230	4.979
1.50	0.124	0.367	0.503	0.671	0.988	1.359	1.849	2.531	2.969	3.476	5.018	6.434	8.463	10.030
	0.220	0.466	0.600	0.744	1.066	1.447	1.913	2.513	2.894	3.359	4.806	6.253	8.166	9.612
2.00	0.305	0.759	0.968	1.221	1.774	2.482	3.298	4.319	4.987	5.848	8.420	10.969	14.208	17.188
	0.386	0.817	1.054	1.306	1.871	2.538	3.355	4.409	5.077	5.894	8.432	10.970	14.326	16.864
2.50	0.612	1.307	1.655	2.143	3.044	4.094	5.456	7.366	8.525	10.121	14.262	19.009	24.601	28.609
	0.651	1.378	1.777	2.203	3.155	4.281	5.659	7.436	8.562	9.940	14.221	18.502	24.161	28.442
3.00	1.002	2.155	2.774	3.440	4.943	6.717	9.148	11.950	13.709	16.304	23.631	30.731	40.538	48.171
	1.035	2.286	2.947	3.653	5.232	7.100	9.386	12.332	14.200	16.486	23.586	30.686	40.071	47.171
3.50	1.658	3.530	4.574	5.656	8.381	11.316	14.835	19.941	23.270	27.100	37.992	49.132	64.628	75.355
	1.776	3.765	4.854	6.018	8.619	11.696	15.461	20.315	23.391	27.157	38.652	50.548	66.009	77.705
4.00	2.805	5.919	7.790	9.709	13.766	19.043	24.941	32.747	37.351	43.274	62.474	81.300	107.420	127.024
	2.922	6.188	7.977	9.890	14.165	19.221	25.408	33.385	38.441	44.629	63.849	83.070	108.476	127.696
4.50	4.574	10.240	13.131	16.292	22.666	30.579	40.588	55.036	63.228	72.643	103.606	134.513	176.647	209.577
	4.600	10.166	13.106	16.249	23.271	31.577	41.743	54.849	63.155	73.321	104.698	136.475	178.218	209.796
5.00	7.853	16.405	20.928	25.348	36.841	51.203	68.709	90.171	102.752	118.424	176.579	224.204	312.967	365.602
	7.865	16.708	21.540	26.706	38.247	51.898	68.606	90.146	103.797	120.504	172.403	224.301	292.507	344.806

** CONDITIONAL QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.073	0.155	0.152	0.223	0.335	0.458	0.608	0.789	0.900	1.066	1.503	1.994	2.602	3.071
	0.070	0.148	0.190	0.236	0.338	0.458	0.606	0.796	0.917	1.064	1.523	1.961	2.567	3.045
1.00	0.130	0.268	0.345	0.431	0.627	0.852	1.123	1.438	1.668	1.989	2.905	3.640	4.927	5.771
	0.131	0.277	0.357	0.442	0.634	0.860	1.137	1.493	1.720	1.996	2.856	3.716	4.852	5.712
1.50	0.225	0.469	0.613	0.768	1.084	1.454	1.973	2.653	3.070	3.566	5.094	6.505	8.531	10.073
	0.230	0.487	0.628	0.779	1.115	1.513	2.000	2.628	3.025	3.512	5.025	6.538	8.537	10.050
2.00	0.364	0.814	1.043	1.273	1.854	2.531	3.354	4.365	5.054	5.918	8.448	11.016	14.211	17.188
	0.387	0.819	1.056	1.309	1.875	2.544	3.363	4.419	5.088	5.907	8.451	10.996	14.359	16.903
2.50	0.650	1.354	1.727	2.166	3.075	4.116	5.501	7.406	8.541	10.176	14.327	19.049	24.601	28.609
	0.653	1.382	1.782	2.209	3.164	4.293	5.675	7.457	8.587	9.969	14.262	18.555	24.231	28.524
3.00	1.014	2.167	2.793	3.470	4.965	6.761	9.154	12.005	13.745	16.325	23.653	30.910	40.538	48.171
	1.068	2.262	2.916	3.615	5.177	7.025	9.287	12.203	14.051	16.312	23.338	30.363	39.650	46.675
3.50	1.716	3.542	4.584	5.705	8.392	11.328	14.853	19.965	23.260	27.109	37.992	49.238	64.628	75.355
	1.738	3.680	4.744	5.882	8.424	11.431	15.111	19.855	22.862	26.542	37.973	49.405	64.516	75.947
4.00	2.805	5.919	7.790	9.709	13.766	19.043	24.941	32.747	37.351	43.274	62.474	81.606	107.420	127.024
	2.866	6.074	7.831	9.710	13.906	18.869	24.944	32.775	37.738	43.813	62.682	81.551	106.494	125.364
4.50	4.574	10.240	13.131	16.292	22.666	30.579	40.588	55.036	63.228	72.643	103.606	134.513	176.647	209.577
	4.740	10.039	12.942	16.046	22.981	31.184	41.223	54.165	62.367	72.406	103.590	134.774	175.996	207.180
5.00	7.853	16.405	20.928	25.348	36.841	51.203	68.709	90.171	102.752	118.424	176.579	224.204	312.967	365.602
	7.934	16.804	21.664	26.860	38.468	52.198	69.002	90.666	104.396	121.200	173.398	225.596	294.598	346.796

TABLE C.1

Varying Arrival Rate(case C-1)

X-LEV	P(TX=0)	T P(TX=0)	X-BAR	ST-DEV	VAR(X-B)	COEF-V
0.50	0.6118	0.6065	0.0558	0.1955	0.0000	2.2778
1.00	0.3552	0.3679	0.2169	0.5289	0.0001	1.6688
1.50	0.2180	0.2231	0.6555	0.9222	0.0002	1.3982
2.00	0.1306	0.1353	1.2136	1.5390	0.0005	1.2661
2.50	0.0766	0.0821	2.0560	2.4371	0.0012	1.1617
3.00	0.0452	0.0498	3.3544	3.7638	0.0028	1.1088
3.50	0.0276	0.0302	5.4264	5.9161	0.0070	1.0898
4.00	0.0170	0.0183	8.5267	9.1269	0.0167	1.0704
4.50	0.0058	0.0111	13.2543	13.7651	0.0379	1.0277
5.00	0.0068	0.0067	20.6057	21.5080	0.0925	1.0438

** INPUT PARAMETERS **

CONSTANT ARRIVAL RATE = 1.00(POISSON)
CONSTANT-LOAD MAGNITUDE = 1.00(EXPONENTIAL)
SHOCK ARRIVAL TIME = CONST LOAD MAG
SHOCK-LOAD MAGNITUDE = 1.00(EXPONENTIAL)

** QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.035	0.071	0.119	0.255	0.508	0.738	0.939
	0.009	0.019	0.025	0.031	0.044	0.059	0.079	0.103	0.119	0.138	0.198	0.257	0.336	0.395
1.00	0.0	0.0	0.0	0.0	0.016	0.084	0.165	0.318	0.416	0.548	0.538	1.372	1.555	2.416
	0.033	0.071	0.091	0.113	0.162	0.220	0.250	0.362	0.439	0.510	0.730	0.949	1.240	1.460
1.50	0.0	0.0	0.018	0.058	0.166	0.300	0.487	0.758	0.928	1.133	1.637	2.564	3.559	4.288
	0.065	0.147	0.190	0.235	0.337	0.457	0.604	0.754	0.914	1.061	1.515	1.576	2.580	3.037
2.00	0.0	0.075	0.141	0.223	0.430	0.677	0.988	1.420	1.690	2.053	3.174	4.224	5.714	7.220
	0.128	0.271	0.349	0.433	0.620	0.841	1.112	1.461	1.682	1.953	2.794	3.636	4.748	5.589
2.50	0.031	0.233	0.361	0.513	0.860	1.268	1.811	2.456	2.967	3.521	5.310	6.975	9.541	11.398
	0.221	0.468	0.604	0.748	1.072	1.454	1.922	2.526	2.908	3.377	4.631	6.285	8.207	9.661
3.00	0.140	0.507	0.729	0.950	1.494	2.133	3.002	4.076	4.807	5.739	8.215	11.013	14.378	16.901
	0.358	0.757	0.976	1.211	1.734	2.353	3.110	4.087	4.706	5.463	7.616	10.169	13.279	15.632
3.50	0.323	0.898	1.212	1.561	2.446	3.528	4.852	6.503	7.545	8.978	13.197	16.593	23.074	27.161
	0.572	1.211	1.562	1.936	2.773	3.763	4.974	6.536	7.525	8.737	12.499	16.262	21.236	24.999
4.00	0.564	1.476	1.989	2.618	3.933	5.655	7.582	10.214	11.938	14.011	20.530	26.718	35.736	41.838
	0.858	1.903	2.453	3.041	4.356	5.910	7.813	10.266	11.821	13.723	19.633	25.544	33.357	39.267
4.50	0.966	2.496	3.406	4.376	6.533	9.117	12.150	16.362	19.214	22.334	31.813	40.476	53.653	61.865
	1.411	2.989	3.853	4.777	6.842	9.284	12.273	16.126	18.568	21.557	30.841	40.126	52.359	61.683
5.00	1.594	4.024	5.545	6.849	10.055	14.072	18.506	25.068	29.053	33.240	47.687	62.447	82.148	100.897
	2.111	4.598	5.928	7.350	10.526	14.283	18.881	24.809	28.566	33.164	47.447	61.729	80.610	94.893

** CONDITIONAL QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.011	0.029	0.040	0.053	0.084	0.125	0.178	0.252	0.301	0.366	0.575	0.742	1.026	1.188
	0.023	0.049	0.064	0.079	0.113	0.153	0.203	0.266	0.306	0.356	0.509	0.662	0.865	1.018
1.00	0.025	0.074	0.099	0.129	0.203	0.285	0.359	0.577	0.686	0.803	1.217	1.702	2.267	2.726
	0.052	0.110	0.142	0.176	0.253	0.343	0.453	0.556	0.666	0.796	1.139	1.482	1.935	2.278
1.50	0.055	0.130	0.179	0.221	0.348	0.509	0.722	0.965	1.150	1.252	2.098	2.801	3.760	4.484
	0.085	0.188	0.243	0.301	0.431	0.565	0.773	1.015	1.169	1.357	1.942	2.526	3.259	3.884
2.00	0.055	0.229	0.310	0.406	0.611	0.879	1.202	1.627	1.910	2.258	3.365	4.464	5.952	7.380
	0.147	0.311	0.402	0.498	0.713	0.968	1.279	1.661	1.935	2.247	3.214	4.182	5.461	6.428
2.50	0.165	0.395	0.534	0.651	1.027	1.461	1.590	2.723	3.166	3.703	5.496	7.208	9.722	11.488
	0.235	0.507	0.654	0.810	1.161	1.575	2.082	2.735	3.150	3.657	5.231	6.806	8.888	10.463
3.00	0.271	0.668	0.875	1.059	1.641	2.285	3.198	4.251	5.034	5.939	8.456	11.201	14.473	17.229
	0.375	0.793	1.023	1.268	1.816	2.464	3.257	4.260	4.928	5.722	8.186	10.650	13.907	16.372
3.50	0.454	1.025	1.356	1.711	2.626	3.681	5.045	6.634	7.714	9.117	13.348	17.161	23.411	27.444
	0.568	1.246	1.606	1.951	2.852	3.809	5.115	6.721	7.739	8.985	12.854	16.724	21.839	25.708
4.00	0.715	1.581	2.145	2.759	4.088	5.811	7.746	10.425	12.086	14.123	20.670	27.062	35.815	41.838
	0.914	1.936	2.495	3.094	4.431	6.012	7.948	10.443	12.025	13.961	19.973	25.985	33.934	39.946
4.50	1.084	2.688	3.530	4.455	6.646	9.259	12.260	16.526	19.375	22.416	31.508	40.745	53.653	61.865
	1.425	3.018	3.891	4.825	6.910	9.376	12.355	16.266	18.752	21.771	31.147	40.523	52.917	62.293
5.00	1.736	4.167	5.679	7.000	10.208	14.173	19.064	25.158	29.185	33.353	47.769	62.538	82.148	100.897
	2.166	4.630	5.968	7.400	10.598	14.381	19.010	24.979	28.761	33.391	47.771	62.152	81.162	95.543

TABLE C.2

Varying Arrival Rate(case C-2)

X-LEV	P(TX=0)	T P(TX=0)	X-BAR	ST-DEV	VAR(X-B)	COEF-V
0.50	0.6058	0.6065	0.3241	0.6430	0.0001	1.9842
1.00	0.3640	0.3679	0.8620	1.2593	0.0003	1.4605
1.50	0.2150	0.2231	1.6572	2.1222	0.0009	1.2804
2.00	0.1334	0.1353	3.0266	3.5169	0.0025	1.1620
2.50	0.0846	0.0821	5.1626	5.8180	0.0068	1.1267
3.00	0.0506	0.0498	8.7357	9.6250	0.0185	1.1022
3.50	0.0296	0.0302	14.7592	16.0825	0.0517	1.0872
4.00	0.0192	0.0183	24.1511	26.0658	0.1359	1.0775
4.50	0.0124	0.0111	39.8202	42.7975	0.3663	1.0746
5.00	0.0076	0.0067	66.0130	70.5290	0.9949	1.0684

** INPUT PARAMETERS **

CONSTANT ARRIVAL RATE = 1.00(POISSON)
CONSTANT-LOAD MAGNITUDE = 1.00(EXPONENTIAL)
SHOCK ARRIVAL TIME = EXP(CONST LOAD MAG)
SHOCK-LOAD MAGNITUDE = 1.00(EXPONENTIAL)

** QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.220	0.397	0.565	1.103	1.656	2.438	2.979
	0.034	0.072	0.093	0.116	0.166	0.225	0.257	0.350	0.449	0.522	0.746	0.971	1.268	1.492
1.00	0.0	0.0	0.0	0.0	0.076	0.329	0.623	1.029	1.266	1.588	2.473	3.435	4.559	5.531
	0.051	0.192	0.248	0.307	0.440	0.597	0.750	1.038	1.195	1.387	1.985	2.582	3.372	3.970
1.50	0.0	0.0	0.092	0.249	0.577	1.004	1.500	2.050	2.462	2.932	4.365	5.661	7.566	9.585
	0.175	0.379	0.488	0.605	0.867	1.176	1.555	2.043	2.353	2.731	3.508	5.084	6.639	7.816
2.00	0.0	0.286	0.520	0.765	1.300	1.921	2.668	3.659	4.306	5.044	7.437	9.804	13.355	15.463
	0.315	0.675	0.871	1.080	1.546	2.098	2.773	3.644	4.196	4.871	6.965	9.067	11.640	13.938
2.50	0.068	0.762	1.145	1.500	2.332	3.350	4.602	6.150	7.095	8.364	12.593	16.599	22.469	27.380
	0.544	1.152	1.485	1.842	2.638	3.579	4.731	6.217	7.158	8.311	11.890	15.465	20.200	23.779
3.00	0.522	1.564	2.068	2.657	3.991	5.560	7.543	10.315	12.170	14.299	21.145	27.919	37.955	42.221
	0.920	1.949	2.513	3.116	4.462	6.055	8.004	10.518	12.110	14.060	20.115	26.170	34.174	40.229
3.50	1.170	2.706	3.631	4.606	6.739	9.482	12.950	17.373	20.578	24.382	35.449	46.773	61.319	73.607
	1.555	3.301	4.256	5.276	7.557	10.254	13.555	17.811	20.508	23.809	34.063	44.317	57.871	68.125
4.00	1.983	4.462	5.878	7.446	11.185	15.842	21.866	29.062	33.541	39.473	56.609	74.354	100.155	120.446
	2.545	5.398	6.959	8.628	12.357	16.768	22.166	29.125	33.536	38.934	55.702	72.470	94.636	111.404
4.50	3.319	7.440	9.747	12.348	18.541	26.539	35.725	47.459	55.234	64.095	94.513	122.060	171.476	198.799
	4.155	8.886	11.456	14.203	20.341	27.601	36.487	47.942	55.202	64.088	91.685	119.291	155.777	183.379
5.00	5.583	12.499	16.602	21.381	31.738	43.186	58.707	77.901	90.318	105.487	157.090	206.688	274.853	318.734
	6.955	14.730	18.991	23.545	33.721	45.757	60.487	79.478	91.513	106.244	152.001	197.757	258.244	304.001

** CONDITIONAL QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.068	0.190	0.240	0.305	0.443	0.575	0.765	0.984	1.113	1.302	1.899	2.465	3.166	3.700
	0.067	0.183	0.236	0.293	0.420	0.570	0.753	0.950	1.140	1.323	1.853	2.463	3.216	3.786
1.00	0.145	0.305	0.391	0.484	0.702	0.955	1.240	1.647	1.877	2.158	3.125	4.020	5.214	6.193
	0.143	0.302	0.390	0.483	0.692	0.939	1.242	1.632	1.879	2.181	3.121	4.060	5.302	6.242
1.50	0.223	0.484	0.633	0.758	1.138	1.537	2.012	2.569	2.975	3.416	4.661	6.414	8.478	10.147
	0.228	0.482	0.622	0.771	1.104	1.499	1.981	2.603	2.997	3.480	4.978	6.477	8.458	9.956
2.00	0.365	0.797	1.009	1.246	1.790	2.406	3.174	4.176	4.782	5.526	8.054	10.470	13.863	16.043
	0.366	0.779	1.005	1.246	1.784	2.421	3.200	4.205	4.842	5.621	8.042	10.463	13.663	16.083
2.50	0.551	1.265	1.591	1.954	2.818	3.844	5.025	6.638	7.597	8.953	13.031	17.099	23.015	27.971
	0.554	1.259	1.623	2.012	2.881	3.910	5.169	6.791	7.820	9.079	12.989	16.898	22.067	25.977
3.00	0.955	1.989	2.503	3.089	4.412	5.979	7.985	10.868	12.631	14.867	21.663	28.306	38.163	42.539
	0.969	2.053	2.647	3.282	4.700	6.378	8.431	11.078	12.756	14.809	21.187	27.565	35.996	42.374
3.50	1.573	3.105	4.016	4.997	7.203	9.966	13.464	17.849	21.064	24.854	35.797	47.401	61.573	74.303
	1.606	3.402	4.386	5.437	7.787	10.567	13.968	18.354	21.133	24.535	35.102	45.668	59.637	70.203
4.00	2.353	4.867	6.259	7.861	11.727	16.383	22.452	29.640	34.080	39.797	57.027	75.639	100.349	120.446
	2.599	5.504	7.096	8.797	12.599	17.096	22.600	29.696	34.192	39.696	56.792	73.889	96.489	113.585
4.50	3.754	7.882	10.302	12.845	18.955	27.199	36.139	48.179	55.574	64.413	94.927	122.593	171.737	198.799
	4.248	8.997	11.599	14.381	20.597	27.948	36.945	48.544	55.896	64.893	92.841	120.788	157.733	185.681
5.00	5.914	13.066	17.195	21.851	32.213	43.662	59.204	78.135	90.899	105.773	157.520	207.008	274.853	318.734
	7.008	14.843	19.136	23.725	33.979	46.107	60.950	80.066	92.214	107.057	153.165	199.272	260.222	306.329

TABLE C.3

Varying Arrival Rate(case C-3)

X-LEV	P(TX=0)	T P(TX=0)	X-BAR	ST-DEV	VAR(X-B)	COEF-V
0.50	0.6068	0.6065	0.2450	0.5062	0.0001	2.0325
1.00	0.3638	0.3679	0.5180	0.7871	0.0001	1.5195
1.50	0.2168	0.2231	0.8436	1.1329	0.0003	1.3430
2.00	0.1278	0.1353	1.3025	1.6464	0.0005	1.2641
2.50	0.0772	0.0821	1.9358	2.3428	0.0011	1.2102
3.00	0.0454	0.0498	2.7565	3.2033	0.0021	1.1621
3.50	0.0330	0.0302	3.6693	4.4855	0.0040	1.1543
4.00	0.0206	0.0183	5.3462	5.9373	0.0071	1.1106
4.50	0.0126	0.0111	7.3127	7.5467	0.0126	1.0808
5.00	0.0078	0.0067	9.7590	10.3573	0.0215	1.0613

** INPUT PARAMETERS **

CONSTANT ARRIVAL RATE = 1.00(POISSON)
CONSTANT-LOAD MAGNITUDE = 1.00(EXPONENTIAL)
SHOCK ARRIVAL TIME = EXP(-CONST LOAD MAG)
SHOCK-LOAD MAGNITUDE = 1.00(EXPONENTIAL)

** QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.171	0.287	0.429	0.861	1.314	1.840	2.322
	0.026	0.056	0.072	0.089	0.127	0.173	0.228	0.300	0.345	0.401	0.573	0.746	0.974	1.147
1.00	0.0	0.0	0.0	0.0	0.044	0.179	0.361	0.587	0.748	0.926	1.510	2.093	2.538	3.598
	0.055	0.116	0.149	0.185	0.265	0.359	0.475	0.624	0.718	0.834	1.193	1.552	2.027	2.386
1.50	0.0	0.0	0.035	0.096	0.239	0.417	0.658	0.965	1.183	1.426	2.281	3.190	4.514	5.147
	0.085	0.188	0.243	0.301	0.431	0.585	0.773	1.016	1.169	1.358	1.942	2.527	3.300	3.885
2.00	0.0	0.083	0.147	0.231	0.437	0.716	1.057	1.501	1.826	2.219	3.357	4.734	6.233	7.455
	0.137	0.291	0.375	0.465	0.665	0.903	1.193	1.568	1.806	2.096	2.999	3.902	5.095	5.998
2.50	0.027	0.158	0.276	0.402	0.724	1.121	1.626	2.323	2.760	3.280	4.957	6.520	8.666	10.884
	0.204	0.432	0.557	0.690	0.989	1.342	1.774	2.331	2.684	3.116	4.457	5.799	7.573	8.915
3.00	0.066	0.290	0.445	0.645	1.091	1.663	2.359	3.347	3.972	4.663	6.649	9.391	12.307	14.793
	0.290	0.615	0.793	0.983	1.408	1.911	2.526	3.319	3.821	4.436	6.347	8.258	10.783	12.694
3.50	0.127	0.473	0.727	0.951	1.634	2.409	3.393	4.024	5.449	6.379	9.745	12.826	17.188	19.594
	0.410	0.868	1.119	1.387	1.987	2.696	3.564	4.683	5.392	6.260	8.955	11.651	15.215	17.911
4.00	0.222	0.782	1.105	1.456	2.357	3.415	4.719	6.360	7.517	9.004	12.574	17.153	22.761	27.134
	0.563	1.193	1.538	1.907	2.731	3.706	4.899	6.437	7.411	8.604	12.310	16.016	20.914	24.620
4.50	0.357	1.162	1.682	2.239	3.391	4.860	6.538	8.988	10.466	12.324	17.526	23.472	30.119	37.001
	0.775	1.641	2.115	2.623	3.756	5.097	6.737	8.852	10.193	11.834	16.930	22.027	28.764	33.861
5.00	0.565	1.797	2.439	3.057	4.707	6.505	8.791	11.881	13.708	15.980	23.210	30.110	40.273	46.316
	1.026	2.178	2.807	3.461	4.985	6.764	8.942	11.750	13.529	15.707	22.471	29.235	38.177	44.942

** CONDITIONAL QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.063	0.142	0.180	0.223	0.328	0.442	0.573	0.748	0.872	1.020	1.462	1.843	2.476	3.025
	0.067	0.141	0.182	0.226	0.324	0.439	0.580	0.763	0.878	1.019	1.458	1.897	2.478	2.917
1.00	0.075	0.163	0.211	0.271	0.397	0.547	0.733	0.958	1.103	1.295	1.904	2.581	3.347	4.029
	0.086	0.182	0.234	0.290	0.416	0.564	0.746	0.980	1.129	1.310	1.875	2.439	3.185	3.750
1.50	0.051	0.197	0.260	0.331	0.478	0.685	0.928	1.250	1.459	1.759	2.680	3.498	4.698	5.419
	0.114	0.241	0.311	0.385	0.552	0.749	0.989	1.300	1.497	1.738	2.487	3.235	4.224	4.973
2.00	0.103	0.236	0.322	0.415	0.638	0.925	1.259	1.752	2.063	2.460	3.703	5.007	6.459	7.740
	0.157	0.333	0.430	0.533	0.763	1.035	1.368	1.798	2.070	2.403	3.438	4.474	5.842	6.877
2.50	0.117	0.306	0.419	0.561	0.908	1.275	1.807	2.506	2.935	3.499	5.142	6.710	9.116	11.056
	0.221	0.468	0.603	0.748	1.072	1.454	1.922	2.526	2.908	3.376	4.830	6.284	8.206	9.661
3.00	0.154	0.418	0.590	0.800	1.249	1.813	2.532	3.534	4.098	4.790	6.968	9.612	12.497	15.120
	0.306	0.647	0.834	1.034	1.481	2.010	2.657	3.491	4.020	4.667	6.677	8.687	11.344	13.354
3.50	0.215	0.593	0.867	1.129	1.768	2.549	3.555	4.756	5.580	6.520	9.857	12.969	17.335	19.837
	0.424	0.897	1.157	1.435	2.055	2.788	3.685	4.842	5.576	6.473	9.261	12.049	15.734	18.522
4.00	0.305	0.895	1.227	1.565	2.474	3.565	4.804	6.458	7.647	9.163	13.175	17.317	22.837	27.321
	0.575	1.218	1.570	1.947	2.788	3.784	5.002	6.572	7.567	8.785	12.569	16.353	21.354	25.138
4.50	0.435	1.257	1.778	2.319	3.529	4.968	6.623	9.124	10.524	12.414	17.612	23.563	30.238	37.001
	0.765	1.662	2.142	2.656	3.804	5.162	6.823	8.965	10.323	11.985	17.146	22.308	29.131	34.293
5.00	0.632	1.858	2.510	3.123	4.778	6.548	8.841	11.959	13.784	16.047	23.259	30.250	40.273	46.316
	1.036	2.195	2.830	3.508	5.024	6.818	9.012	11.842	13.635	15.830	22.648	29.465	36.478	45.295

TABLE D.1

Pareto Distribution(case D-1)

X-LEV	P(TX=0)	T P(TX=0)	X-BAR	ST-DEV	VAR(X-B)	COEF-V
0.50	0.6704	0.6667	0.1517	0.3457	0.0000	2.2788
1.00	0.5070	0.5000	0.3131	0.5541	0.0001	1.7696
1.50	0.4016	0.4000	0.5165	0.8054	0.0001	1.5775
2.00	0.3370	0.3333	0.7774	1.1248	0.0003	1.4465
2.50	0.2852	0.2857	1.0541	1.5055	0.0005	1.3764
3.00	0.2538	0.2500	1.4538	1.9252	0.0007	1.3270
3.50	0.2250	0.2222	1.8450	2.3469	0.0011	1.2720
4.00	0.2032	0.2000	2.3101	2.8679	0.0016	1.2415
4.50	0.1864	0.1918	2.7638	3.3656	0.0023	1.2192
5.00	0.1716	0.1667	3.2817	3.9839	0.0032	1.2140

** INPUT PARAMETERS **

CONSTANT ARRIVAL RATE = 1.00(POISSON)
CONSTANT-LOAD MAGNITUDE = PARETO (α=1)
SHOCK ARRIVAL RATE = 2.00(POISSON)
SHOCK-LOAD MAGNITUDE = 1.00(EXPONENTIAL)

** QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.041	0.120	0.221	0.548	0.885	1.307	1.614
	0.016	0.034	0.044	0.054	0.077	0.105	0.139	0.163	0.210	0.244	0.349	0.454	0.593	0.699
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.124	0.256	0.416	0.567	1.029	1.460	2.064	2.497
	0.033	0.070	0.090	0.112	0.160	0.217	0.287	0.377	0.434	0.504	0.721	0.938	1.225	1.442
1.50	0.0	0.0	0.0	0.0	0.0	0.141	0.318	0.568	0.739	0.934	1.525	2.155	2.923	3.555
	0.054	0.114	0.147	0.182	0.261	0.354	0.468	0.615	0.708	0.822	1.175	1.529	1.997	2.351
2.00	0.0	0.0	0.0	0.0	0.108	0.298	0.571	0.904	1.151	1.415	2.251	3.016	4.242	5.013
	0.082	0.173	0.224	0.277	0.397	0.539	0.712	0.936	1.078	1.251	1.790	2.329	3.041	3.560
2.50	0.0	0.0	0.0	0.022	0.234	0.510	0.844	1.331	1.583	1.920	3.020	4.158	5.670	6.796
	0.115	0.244	0.315	0.390	0.559	0.758	1.003	1.317	1.517	1.761	2.519	3.278	4.280	5.039
3.00	0.0	0.0	0.0	0.109	0.391	0.725	1.182	1.728	2.136	2.565	3.940	5.433	7.222	8.420
	0.153	0.324	0.418	0.519	0.743	1.008	1.332	1.750	2.015	2.340	3.347	4.355	5.687	6.695
3.50	0.0	0.0	0.070	0.220	0.549	0.989	1.529	2.216	2.704	3.265	4.957	6.056	8.657	10.497
	0.194	0.412	0.531	0.658	0.943	1.279	1.691	2.222	2.558	2.970	4.249	5.528	7.218	8.497
4.00	0.0	0.0	0.152	0.341	0.771	1.301	1.959	2.835	3.420	4.068	6.128	8.146	10.921	12.430
	0.243	0.515	0.665	0.824	1.180	1.601	2.117	2.761	3.202	3.718	5.319	6.920	9.037	10.638
4.50	0.0	0.054	0.236	0.449	0.969	1.616	2.428	3.352	3.976	4.726	7.112	10.018	12.661	14.949
	0.291	0.617	0.795	0.986	1.412	1.916	2.532	3.328	3.831	4.448	6.364	8.280	10.812	12.728
5.00	0.0	0.110	0.362	0.616	1.239	1.960	2.858	3.971	4.694	5.593	8.486	11.347	14.863	17.869
	0.346	0.732	0.944	1.170	1.676	2.275	3.007	3.951	4.549	5.282	7.556	9.831	12.838	15.113

** CONDITIONAL QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.045	0.098	0.126	0.153	0.226	0.308	0.409	0.554	0.637	0.752	1.076	1.380	1.816	2.211
	0.048	0.103	0.132	0.164	0.235	0.319	0.422	0.554	0.638	0.741	1.060	1.379	1.801	2.120
1.00	0.065	0.130	0.168	0.209	0.305	0.428	0.576	0.782	0.903	1.036	1.475	1.901	2.497	3.001
	0.067	0.142	0.183	0.227	0.324	0.440	0.582	0.765	0.880	1.022	1.462	1.903	2.485	2.925
1.50	0.083	0.173	0.224	0.280	0.411	0.569	0.761	1.021	1.196	1.373	1.995	2.590	3.302	3.966
	0.090	0.190	0.245	0.304	0.436	0.591	0.782	1.027	1.183	1.373	1.964	2.555	3.337	3.928
2.00	0.111	0.229	0.304	0.383	0.575	0.795	1.072	1.419	1.620	1.900	2.725	3.535	4.658	5.622
	0.124	0.262	0.337	0.418	0.599	0.813	1.074	1.412	1.625	1.887	2.700	3.513	4.587	5.400
2.50	0.143	0.320	0.415	0.522	0.759	1.044	1.403	1.814	2.122	2.494	3.591	4.707	6.275	7.201
	0.162	0.343	0.443	0.549	0.786	1.067	1.410	1.853	2.134	2.477	3.544	4.611	6.022	7.089
3.00	0.182	0.400	0.510	0.645	0.932	1.322	1.735	2.348	2.697	3.138	4.555	6.065	7.641	9.134
	0.205	0.435	0.560	0.695	0.995	1.350	1.785	2.346	2.701	3.136	4.486	5.836	7.621	8.972
3.50	0.226	0.475	0.615	0.782	1.167	1.616	2.202	2.857	3.352	3.861	5.622	7.170	9.535	11.021
	0.251	0.531	0.685	0.849	1.216	1.650	2.182	2.866	3.301	3.832	5.482	7.132	9.314	10.964
4.00	0.281	0.589	0.781	0.987	1.432	1.965	2.643	3.561	4.075	4.692	6.730	8.898	11.396	13.264
	0.305	0.647	0.834	1.034	1.481	2.010	2.657	3.491	4.019	4.666	6.676	8.685	11.342	13.351
4.50	0.313	0.696	0.924	1.148	1.685	2.343	3.135	4.065	4.673	5.480	7.897	10.640	13.454	16.209
	0.358	0.758	0.977	1.212	1.735	2.355	3.113	4.090	4.709	5.467	7.822	10.177	13.289	15.644
5.00	0.378	0.840	1.087	1.362	1.979	2.744	3.554	4.723	5.454	6.389	9.373	12.036	15.919	18.282
	0.417	0.884	1.140	1.413	2.024	2.747	3.631	4.771	5.493	6.377	9.124	11.870	15.501	18.248

TABLE D.2

Pareto Distribution(case D-2)

X-LEV	P(TX=0)	T P(TX=0)	X-BAR	ST-DEV	VAR(X-B)	COEF-V
0.50	0.4462	0.4444	0.2564	0.4813	0.0000	1.6127
1.00	0.2830	0.2500	0.5558	0.7711	0.0001	1.2942
1.50	0.1678	0.1600	0.9875	1.2201	0.0003	1.2356
2.00	0.1140	0.1111	1.5428	1.7735	0.0006	1.1456
2.50	0.0840	0.0816	2.3234	2.5854	0.0013	1.1126
3.00	0.0626	0.0625	3.4404	3.7599	0.0028	1.0958
3.50	0.0506	0.0494	5.0213	5.3755	0.0058	1.0693
4.00	0.0362	0.0400	7.0037	7.4257	0.0110	1.0602
4.50	0.0332	0.0331	9.4057	9.9506	0.0198	1.0575
5.00	0.0312	0.0278	12.5503	13.8736	0.0385	1.0713

** INPUT PARAMETERS **

CONSTANT ARRIVAL RATE = 1.00(POISSON)
CONSTANT-LOAD MAGNITUDE = PARETO (α =2)
SHOCK ARRIVAL RATE = 2.00(POISSON)
SHOCK-LOAD MAGNITUDE = 1.00(EXPONENTIAL)

** QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.0	0.0	0.0	0.0	0.0	0.053	0.173	0.331	0.419	0.542	0.523	1.282	1.793	2.204
	0.031	0.067	0.086	0.106	0.152	0.207	0.273	0.359	0.414	0.480	0.687	0.894	1.168	1.374
1.00	0.0	0.0	0.0	0.049	0.174	0.324	0.458	0.727	0.809	1.046	1.614	2.620	2.901	3.418
	0.063	0.133	0.171	0.213	0.304	0.413	0.546	0.717	0.826	0.959	1.372	1.785	2.331	2.744
1.50	0.0	0.042	0.116	0.157	0.370	0.572	0.841	1.165	1.409	1.660	2.558	3.279	4.621	5.709
	0.104	0.220	0.284	0.352	0.504	0.684	0.905	1.189	1.369	1.589	2.274	2.958	3.863	4.548
2.00	0.0	0.156	0.262	0.374	0.634	0.558	1.377	1.876	2.159	2.626	3.651	5.058	6.720	8.009
	0.163	0.344	0.444	0.550	0.788	1.069	1.414	1.857	2.139	2.483	3.552	4.622	6.035	7.105
2.50	0.028	0.304	0.450	0.627	1.020	1.517	2.071	2.804	3.283	3.903	5.676	7.565	9.763	11.490
	0.245	0.518	0.668	0.829	1.187	1.610	2.129	2.757	3.221	3.739	5.350	6.960	9.089	10.700
3.00	0.116	0.522	0.757	0.987	1.584	2.244	3.072	4.203	4.846	5.649	8.295	10.528	14.553	17.341
	0.362	0.768	0.990	1.227	1.757	2.385	3.152	4.142	4.769	5.537	7.922	10.306	13.459	15.844
3.50	0.267	0.850	1.152	1.572	2.331	3.296	4.499	6.114	7.135	8.441	12.058	15.874	20.066	23.822
	0.530	1.122	1.446	1.793	2.568	3.485	4.606	6.053	6.969	8.091	11.576	15.060	19.667	23.151
4.00	0.434	1.252	1.705	2.173	3.341	4.680	6.430	8.532	9.769	11.336	16.693	21.452	29.243	33.535
	0.738	1.563	2.015	2.498	3.578	4.855	6.417	8.432	9.709	11.272	16.127	20.981	27.399	32.253
4.50	0.644	1.744	2.367	3.061	4.622	6.389	8.617	11.359	13.256	15.357	21.861	28.601	38.111	45.260
	0.991	2.099	2.706	3.355	4.805	6.520	8.618	11.324	13.039	15.138	21.657	28.177	36.795	43.315
5.00	0.911	2.422	3.287	4.285	6.232	8.608	11.530	15.357	17.935	20.899	30.697	40.546	53.518	63.116
	1.364	2.890	3.726	4.619	6.615	8.976	11.860	15.552	17.953	20.843	29.819	38.796	50.662	59.638

** CONDITIONAL QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.053	0.119	0.151	0.194	0.274	0.376	0.484	0.652	0.749	0.871	1.237	1.652	2.153	2.473
	0.057	0.120	0.155	0.192	0.275	0.374	0.494	0.649	0.747	0.867	1.241	1.614	2.108	2.482
1.00	0.061	0.176	0.227	0.286	0.407	0.552	0.729	0.956	1.101	1.277	1.840	2.419	3.156	3.695
	0.064	0.178	0.229	0.284	0.407	0.553	0.731	0.960	1.106	1.284	1.837	2.389	3.120	3.673
1.50	0.116	0.250	0.329	0.359	0.573	0.789	1.059	1.415	1.609	1.895	2.777	3.662	4.944	5.859
	0.125	0.265	0.341	0.423	0.606	0.822	1.087	1.429	1.645	1.910	2.732	3.555	4.642	5.465
2.00	0.161	0.356	0.448	0.573	0.855	1.192	1.550	2.084	2.434	2.813	4.050	5.341	6.957	8.066
	0.183	0.389	0.501	0.621	0.889	1.207	1.596	2.056	2.414	2.802	4.009	5.216	6.812	8.019
2.50	0.232	0.517	0.654	0.865	1.254	1.726	2.306	3.031	3.537	4.150	5.511	7.787	10.060	11.709
	0.267	0.566	0.730	0.905	1.296	1.758	2.324	3.054	3.516	4.082	5.840	7.599	9.923	11.681
3.00	0.341	0.760	0.980	1.247	1.759	2.509	3.352	4.463	5.087	5.935	8.541	11.222	14.555	17.698
	0.387	0.820	1.057	1.310	1.877	2.547	3.366	4.423	5.093	5.913	8.460	11.006	14.373	16.920
3.50	0.523	1.112	1.474	1.805	2.610	3.568	4.748	6.357	7.461	8.737	12.373	16.082	20.243	23.652
	0.558	1.182	1.523	1.889	2.705	3.670	4.852	6.375	7.341	8.522	12.193	15.663	20.715	24.385
4.00	0.700	1.527	1.958	2.502	3.643	4.956	6.714	8.776	9.987	11.655	16.979	21.849	25.347	33.823
	0.767	1.625	2.055	2.597	3.720	5.047	6.672	8.767	10.095	11.720	16.767	21.815	28.467	33.534
4.50	0.950	2.031	2.702	3.429	4.667	6.701	8.946	11.675	13.342	15.714	22.146	28.600	36.459	45.359
	1.025	2.171	2.799	3.470	4.970	6.743	8.914	11.713	13.487	15.658	22.401	29.145	38.059	44.802
5.00	1.276	2.830	3.746	4.654	6.617	9.040	11.534	15.809	18.326	21.421	31.400	40.950	53.571	63.496
	1.408	2.983	3.846	4.768	6.828	9.260	12.248	16.054	18.531	21.514	30.779	40.045	52.253	61.559

TABLE D.3

Pareto Distribution(case D-3)

X-LEV	P(TX=0)	T P(TX=0)	X-BAR	ST-DEV	VAR(X-B)	COEF-V
0.50	0.6716	0.6667	0.1485	0.3344	0.0000	2.2505
1.00	0.5026	0.5000	0.2877	0.5091	0.0001	1.7695
1.50	0.3562	0.4000	0.4261	0.6423	0.0001	1.5074
2.00	0.3330	0.3333	0.5576	0.7894	0.0001	1.4156
2.50	0.2834	0.2857	0.6527	0.9184	0.0002	1.3258
3.00	0.2516	0.2500	0.8283	1.0573	0.0002	1.2765
3.50	0.2158	0.2222	0.9656	1.1933	0.0003	1.2306
4.00	0.1568	0.2000	1.1078	1.3316	0.0004	1.2020
4.50	0.1824	0.1818	1.2548	1.4900	0.0004	1.1874
5.00	0.1656	0.1667	1.3960	1.6557	0.0005	1.1861

** INPUT PARAMETERS **

CONSTANT ARRIVAL RATE = 1.00(POISSON)
CONSTANT-LOAD MAGNITUDE = PARETO (α=1)
SHOCK ARRIVAL RATE = 2.00(POISSON)
SHOCK-LOAD MAGNITUDE = PARETO (α=1)

** QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.043	0.124	0.227	0.533	0.853	1.302	1.590
	0.016	0.033	0.043	0.053	0.076	0.103	0.136	0.179	0.206	0.239	0.342	0.445	0.581	0.664
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.125	0.251	0.380	0.508	0.921	1.365	1.923	2.238
	0.020	0.064	0.083	0.103	0.147	0.199	0.264	0.346	0.399	0.463	0.663	0.862	1.126	1.325
1.50	0.0	0.0	0.0	0.0	0.003	0.132	0.254	0.479	0.613	0.782	1.306	1.769	2.313	2.848
	0.045	0.095	0.123	0.152	0.218	0.295	0.390	0.513	0.591	0.686	0.981	1.277	1.667	1.962
2.00	0.0	0.0	0.0	0.0	0.088	0.244	0.418	0.652	0.812	1.022	1.592	2.173	2.549	3.517
	0.059	0.124	0.160	0.199	0.285	0.386	0.511	0.671	0.773	0.897	1.284	1.670	2.181	2.568
2.50	0.0	0.0	0.0	0.026	0.168	0.346	0.549	0.829	1.039	1.251	1.523	2.611	3.468	3.978
	0.073	0.155	0.199	0.247	0.354	0.480	0.635	0.834	0.960	1.115	1.595	2.075	2.710	3.190
3.00	0.0	0.0	0.0	0.078	0.248	0.434	0.688	1.027	1.239	1.469	2.253	3.014	3.921	4.588
	0.087	0.185	0.238	0.295	0.423	0.574	0.759	0.997	1.148	1.333	1.907	2.481	3.240	3.815
3.50	0.0	0.0	0.058	0.127	0.325	0.542	0.819	1.213	1.435	1.711	2.602	3.434	4.465	5.150
	0.102	0.216	0.279	0.345	0.495	0.672	0.888	1.167	1.344	1.561	2.233	2.905	3.793	4.465
4.00	0.0	0.005	0.102	0.157	0.400	0.647	0.972	1.362	1.612	1.923	2.946	3.674	4.920	5.922
	0.117	0.247	0.319	0.395	0.566	0.768	1.015	1.334	1.536	1.783	2.551	3.319	4.334	5.101
4.50	0.0	0.043	0.136	0.245	0.465	0.745	1.110	1.530	1.829	2.174	3.262	4.272	5.626	6.504
	0.132	0.280	0.361	0.448	0.641	0.870	1.150	1.511	1.740	2.020	2.889	3.759	4.909	5.779
5.00	0.0	0.071	0.176	0.294	0.533	0.846	1.213	1.708	2.003	2.390	3.618	4.668	6.163	7.188
	0.147	0.312	0.402	0.498	0.713	0.968	1.279	1.681	1.935	2.247	3.214	4.182	5.461	6.429

** CONDITIONAL QUANTILE OF TX **

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.50	0.050	0.104	0.128	0.156	0.235	0.307	0.403	0.537	0.621	0.726	1.066	1.393	1.757	2.052
	0.048	0.101	0.130	0.161	0.231	0.314	0.414	0.545	0.627	0.728	1.042	1.355	1.770	2.083
1.00	0.062	0.127	0.164	0.199	0.294	0.384	0.509	0.661	0.792	0.923	1.377	1.770	2.238	2.706
	0.061	0.129	0.166	0.206	0.296	0.401	0.530	0.656	0.802	0.931	1.332	1.733	2.263	2.664
1.50	0.077	0.159	0.201	0.255	0.362	0.473	0.635	0.857	0.999	1.154	1.639	2.087	2.706	3.158
	0.074	0.157	0.203	0.252	0.361	0.489	0.647	0.850	0.978	1.136	1.625	2.114	2.761	3.250
2.00	0.087	0.184	0.243	0.298	0.416	0.566	0.758	1.022	1.170	1.369	1.949	2.525	3.249	3.818
	0.088	0.187	0.240	0.298	0.427	0.579	0.766	1.006	1.159	1.345	1.925	2.504	3.270	3.850
2.50	0.101	0.214	0.280	0.342	0.474	0.659	0.881	1.165	1.372	1.577	2.246	2.925	3.740	4.305
	0.102	0.216	0.278	0.345	0.494	0.670	0.886	1.164	1.340	1.556	2.226	2.896	3.782	4.452
3.00	0.118	0.250	0.315	0.385	0.555	0.758	1.039	1.347	1.541	1.789	2.611	3.315	4.224	4.784
	0.117	0.247	0.318	0.395	0.565	0.767	1.014	1.333	1.534	1.781	2.548	3.316	4.330	5.097
3.50	0.134	0.282	0.358	0.433	0.625	0.854	1.167	1.506	1.729	1.991	2.909	3.735	4.748	5.581
	0.131	0.277	0.358	0.443	0.635	0.861	1.139	1.456	1.723	2.000	2.862	3.723	4.862	5.723
4.00	0.147	0.312	0.396	0.483	0.655	0.963	1.276	1.651	1.919	2.240	3.234	4.117	5.137	6.103
	0.145	0.308	0.397	0.492	0.705	0.956	1.264	1.661	1.912	2.220	3.176	4.132	5.395	6.351
4.50	0.166	0.344	0.432	0.533	0.779	1.076	1.405	1.849	2.130	2.492	3.636	4.527	6.004	6.770
	0.162	0.342	0.442	0.547	0.784	1.064	1.406	1.848	2.128	2.470	3.534	4.598	6.004	7.068
5.00	0.164	0.373	0.470	0.569	0.849	1.161	1.504	2.008	2.334	2.752	3.677	5.137	6.455	7.538
	0.177	0.375	0.484	0.600	0.859	1.165	1.540	2.024	2.330	2.706	3.871	5.036	6.576	7.742

TABLE E.1

$\chi(x)$ and $\gamma^{\#}(x)$ (case E)

```
** INPUT DATA **
CONSTANT-L ARRIVAL=        1.00(POISSON)
CONSTANT-L MAG=        1.00(EXP)
SHOCK ARRIVAL RATE=        1.00(POISSON)
SHOCK-L MAG=        1.00(EXP)
```

X-LEV	P(TX=0)	TRUE PR	X-BAR	T X-BAR	ST-DEVI	VAR(X-BAR)	COEF-V
0.20	0.82250	0.81873	0.10210	0.10535	0.33369	0.00001	3.23648
0.40	0.67360	0.67032	0.21618	0.22294	0.49075	0.00002	2.27015
0.60	0.54720	0.54881	0.35313	0.35540	0.66996	0.00004	1.89720
0.80	0.44530	0.44932	0.50663	0.50583	0.83743	0.00007	1.65229
1.00	0.36300	0.36788	0.67670	0.67783	1.01830	0.00010	1.50460
1.20	0.25780	0.30119	0.86512	0.87563	1.20952	0.00015	1.35166
1.40	0.23570	0.24660	1.10049	1.10412	1.43325	0.00021	1.30238
1.60	0.19590	0.20190	1.36618	1.36902	1.70063	0.00029	1.24481
1.80	0.15650	0.16530	1.67575	1.67703	2.00288	0.00040	1.19522
2.00	0.12650	0.13534	2.05553	2.03604	2.41529	0.00056	1.17331
2.20	0.10350	0.11080	2.47730	2.45525	2.82038	0.00080	1.13849
2.40	0.08510	0.09072	2.96962	2.94574	3.29962	0.00105	1.11105
2.60	0.07020	0.07427	3.54663	3.52031	3.90525	0.00153	1.10050
2.80	0.05620	0.06081	4.24761	4.19432	4.62879	0.00214	1.08969
3.00	0.04660	0.04979	4.55160	4.56595	5.32632	0.00284	1.06701

** $\chi(x)$, 1/E(TX), $\gamma^{\#}(x)$ **

X-LEV	0.200	0.400	0.600	0.800	1.000	1.200	1.400	1.600	1.800	2.000	2.200	2.400	2.600	2.800	3.000
$\chi(x)$	1.708	1.459	1.247	1.066	0.912	0.780	0.667	0.570	0.487	0.417	0.355	0.303	0.259	0.221	0.188
1/E(T)	9.452	4.486	2.814	1.977	1.475	1.142	0.906	0.730	0.596	0.491	0.407	0.339	0.284	0.238	0.201
$\gamma^{\#}(x)$	5.942	3.254	2.364	1.923	1.670	1.502	1.386	1.303	1.238	1.193	1.155	1.125	1.102	1.085	1.068

TABLE E.2

Quantiles (case E)

*** QUANTILE OF T X ***

X-LEV	Q.1	Q.2	Q.25	Q.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	Q.98	Q.99
0.20	0.0 0.0 0.011	0.0 0.0 0.024	0.0 0.0 0.030	0.0 0.0 0.038	0.0 0.0 0.054	0.0 0.0 0.073	0.0 0.0 0.097	0.0 0.0 0.127	0.0 0.0 0.146	0.0 0.0 0.170	0.336 0.305 0.243	0.772 0.711 0.316	1.234 1.247 0.412	1.639 1.653 0.485
0.40	0.0 0.0 0.023	0.0 0.0 0.050	0.0 0.0 0.064	0.0 0.0 0.080	0.0 0.0 0.114	0.0 0.0 0.155	0.0 0.0 0.204	0.060 0.017 0.268	0.178 0.142 0.309	0.327 0.295 0.359	0.786 0.770 0.513	1.231 1.245 0.668	1.912 1.873 0.872	2.304 2.348 1.027
0.60	0.0 0.0 0.037	0.0 0.0 0.079	0.0 0.0 0.102	0.0 0.0 0.127	0.0 0.0 0.182	0.0 0.0 0.246	0.055 0.045 0.326	0.311 0.276 0.428	0.449 0.422 0.453	0.619 0.601 0.572	1.151 1.157 0.818	1.744 1.712 1.065	2.484 2.447 1.350	3.086 3.003 1.637
0.80	0.0 0.0 0.053	0.0 0.0 0.113	0.0 0.0 0.146	0.0 0.0 0.180	0.0 0.0 0.258	0.095 0.037 0.351	0.294 0.246 0.463	0.545 0.516 0.609	0.710 0.687 0.701	0.922 0.896 0.814	1.560 1.547 1.165	2.226 2.191 1.515	3.117 3.057 1.979	3.680 3.707 2.329
1.00	0.0 0.0 0.071	0.0 0.0 0.151	0.0 0.0 0.195	0.0 0.0 0.242	0.065 0.0 0.346	0.249 0.198 0.410	0.467 0.443 0.621	0.769 0.758 0.816	0.971 0.958 0.940	1.208 1.203 1.091	1.599 1.963 1.561	2.779 2.724 2.031	3.689 3.729 2.652	4.506 4.489 3.122
1.20	0.0 0.0 0.052	0.0 0.0 0.195	0.0 0.0 0.252	0.003 0.0 0.312	0.187 0.133 0.447	0.402 0.367 0.607	0.664 0.653 0.802	1.027 1.012 1.054	1.254 1.256 1.214	1.545 1.542 1.409	2.447 2.432 2.016	3.340 3.321 2.623	4.478 4.456 3.425	5.394 5.385 4.032
1.40	0.0 0.0 0.116	0.0 0.0 0.246	0.018 0.0 0.318	0.113 0.045 0.354	0.324 0.276 0.564	0.581 0.550 0.765	0.503 0.885 1.012	1.370 1.316 1.329	1.601 1.590 1.531	1.944 1.925 1.777	3.005 2.964 2.542	3.996 4.004 3.208	5.335 5.379 4.319	6.396 6.419 5.085
1.60	0.0 0.0 0.144	0.007 0.0 0.305	0.115 0.041 0.394	0.223 0.162 0.488	0.455 0.433 0.659	0.774 0.752 0.949	1.151 1.144 1.254	1.668 1.649 1.648	1.984 1.969 1.898	2.392 2.360 2.203	3.558 3.516 3.152	4.766 4.792 4.101	6.353 6.400 5.356	7.623 7.616 6.305
1.80	0.0 0.0 0.177	0.101 0.019 0.374	0.220 0.152 0.482	0.345 0.294 0.358	0.645 0.611 0.857	1.002 0.985 1.162	1.473 1.444 1.537	2.059 2.035 2.019	2.447 2.410 2.325	2.884 2.868 2.699	4.260 4.293 3.862	5.665 5.717 5.024	7.609 7.600 6.561	8.943 9.024 7.723
2.00	0.0 0.0 0.215	0.198 0.113 0.454	0.332 0.268 0.586	0.476 0.433 0.726	0.845 0.803 1.040	1.267 1.241 1.411	1.839 1.777 1.866	2.513 2.468 2.451	2.941 2.905 2.823	3.462 3.441 3.277	5.114 5.105 4.688	6.813 6.769 6.099	9.104 8.969 7.965	10.895 10.633 9.376
2.20	0.0 0.0 0.255	0.304 0.223 0.548	0.452 0.405 0.706	0.642 0.559 0.876	1.059 1.033 1.254	1.599 1.546 1.702	2.213 2.173 2.250	3.040 2.983 2.956	3.493 3.495 3.404	4.122 4.123 3.952	6.072 6.073 5.654	8.084 8.023 7.355	10.870 10.601 9.605	13.075 12.550 11.307
2.40	0.045 0.0 0.310	0.398 0.348 0.657	0.595 0.561 0.847	0.835 0.789 1.051	1.352 1.297 1.505	1.548 1.898 2.042	2.701 2.634 2.699	3.610 3.582 3.547	4.192 4.183 4.084	4.903 4.919 4.741	7.158 7.205 6.783	9.477 9.490 8.825	12.913 12.511 11.524	15.031 14.797 13.566
2.60	0.117 0.033 0.371	0.523 0.488 0.786	0.797 0.737 1.013	1.039 1.004 1.256	1.662 1.559 1.758	2.347 2.304 2.440	3.191 3.165 3.226	4.242 4.277 4.238	4.913 4.981 4.880	5.814 5.843 5.666	8.513 8.520 8.106	11.420 11.158 10.546	15.234 14.737 13.772	17.831 17.415 16.212
2.80	0.165 0.109 0.442	0.700 0.641 0.936	0.572 0.932 1.207	1.254 1.244 1.456	1.981 1.940 2.143	2.827 2.763 2.907	3.753 3.771 3.843	5.036 5.069 5.050	5.907 5.893 5.815	6.864 6.900 6.751	10.132 10.030 9.658	13.668 13.159 12.565	17.805 17.296 16.408	21.155 20.426 19.316
3.00	0.232 0.208 0.525	0.872 0.833 1.113	1.184 1.175 1.434	1.555 1.542 1.778	2.380 2.360 2.547	3.337 3.327 3.456	4.458 4.511 4.569	5.915 6.038 6.003	6.892 7.005 6.912	8.177 8.189 8.025	12.086 11.667 11.481	15.933 15.545 14.937	20.633 20.407 19.505	23.946 24.085 22.961

TABLE F.1

$\lambda(x)$ and $\gamma^{*}(x)$ (case F)

** INPUT DATA **
CONSTANT-L ARRIVAL= 1.00(POISSON)
CONSTANT-L MAG= 2.00(EXP)
SHOCK ARRIVAL RATE= 1.00(POISSON)
SHOCK-L MAG= 1.00(EXP)

X-LEV	P(TX=0)	TRUE PR	X-BAR	T X-BAR	ST-DEVI	VAR(X-BAR)	COEF-V
0.20	0.66570	0.67032	0.21047	0.21009	0.46512	0.00002	2.20996
0.40	0.44510	0.44933	0.43515	0.44149	0.70431	0.00005	1.61840
0.60	0.30100	0.30119	0.69278	0.69778	0.94643	0.00009	1.36612
0.80	0.20110	0.20190	0.98280	0.98504	1.21559	0.00015	1.23687
1.00	0.13270	0.13534	1.30911	1.31172	1.51946	0.00023	1.16068
1.20	0.08850	0.09072	1.68864	1.68860	1.87235	0.00035	1.11010
1.40	0.05870	0.06081	2.12442	2.12882	2.27115	0.00052	1.06907
1.60	0.04080	0.04076	2.63433	2.64819	2.78008	0.00077	1.05532
1.80	0.02700	0.02732	3.24295	3.26570	3.32625	0.00111	1.02568
2.00	0.01800	0.01832	4.01151	4.00415	4.08579	0.00167	1.01841
2.20	0.01250	0.01228	4.91615	4.89106	4.99251	0.00249	1.01553
2.40	0.00840	0.00823	5.94709	5.95976	5.97537	0.00357	1.00475
2.60	0.00600	0.00552	7.25828	7.25071	7.34602	0.00540	1.01237
2.80	0.00410	0.00370	8.91776	8.81314	9.07498	0.00824	1.01763
3.00	0.00220	0.00248	10.78987	10.70696	10.97682	0.01205	1.01921

** λ(X), 1/E(TX), γ^{*}(X) **

X-LEV	0.200	0.400	0.600	0.800	1.000	1.200	1.400	1.600	1.800	2.000	2.200	2.400	2.600	2.800	3.000
λ(X)	1.563	1.237	0.975	0.801	0.650	0.531	0.435	0.358	0.256	0.244	0.199	0.166	0.136	0.112	0.092
1/E(T)	4.760	2.265	1.433	1.015	0.762	0.592	0.470	0.378	0.306	0.250	0.204	0.168	0.138	0.113	0.093
γ^{*}(X)	3.109	1.860	1.400	1.286	1.183	1.122	1.084	1.059	1.044	1.032	1.019	1.017	1.011	1.007	1.005

TABLE F.2

Quantiles (case F)

*** QUANTILE OF T X ***

-LEV	Q.1	Q.2	Q.25	C.3	Q.4	Q.5	Q.6	Q.7	Q.75	Q.8	Q.9	Q.95	C.98	Q.99
0.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.067	0.192	0.327	0.765	1.205	1.765	2.146
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.044	0.161	0.304	0.747	1.191	1.777	2.221
	0.022	0.047	0.060	0.075	0.107	0.146	0.153	0.253	0.291	0.338	0.484	0.629	0.822	0.967
0.40	0.0	0.0	0.0	0.0	0.0	0.077	0.258	0.462	0.619	0.806	1.343	1.885	2.556	3.190
	0.0	0.0	0.0	0.0	0.0	0.059	0.239	0.471	0.619	0.799	1.359	1.919	2.660	3.220
	0.047	0.099	0.127	0.157	0.226	0.306	0.405	0.532	0.612	0.711	1.017	1.323	1.727	2.033
0.60	0.0	0.0	0.0	0.0	0.154	0.341	0.561	0.852	1.032	1.253	1.991	2.561	3.514	4.195
	0.0	0.0	0.0	0.020	0.179	0.366	0.555	0.850	1.077	1.306	2.017	2.728	3.668	4.379
	0.074	0.156	0.201	0.249	0.356	0.484	0.639	0.840	0.967	1.123	1.607	2.090	2.730	3.213
0.80	0.0	0.0	0.075	0.162	0.332	0.571	0.850	1.265	1.409	1.698	2.551	3.387	4.630	5.477
	0.0	0.0	0.045	0.131	0.324	0.552	0.830	1.150	1.417	1.696	2.562	3.428	4.572	5.438
	0.104	0.220	0.283	0.351	0.503	0.683	0.503	1.166	1.366	1.585	2.268	2.951	3.854	4.536
1.00	0.0	0.118	0.219	0.317	0.545	0.823	1.160	1.581	1.871	2.208	3.242	4.381	5.787	6.947
	0.0	0.085	0.184	0.250	0.527	0.808	1.151	1.554	1.874	2.217	3.286	4.350	5.759	6.826
	0.128	0.293	0.377	0.468	0.610	0.909	1.202	1.519	1.818	2.111	3.020	3.930	5.131	6.041
1.20	0.024	0.235	0.350	0.476	0.765	1.109	1.510	2.027	2.375	2.795	4.128	5.419	7.281	8.474
	0.0	0.204	0.325	0.455	0.746	1.089	1.510	2.052	2.395	2.816	4.122	5.428	7.154	8.460
	0.178	0.377	0.486	0.602	0.863	1.170	1.547	2.023	2.341	2.718	3.888	5.059	6.606	7.776
1.40	0.051	0.351	0.493	0.644	1.025	1.426	1.910	2.559	2.975	3.490	5.064	6.740	8.816	10.240
	0.056	0.326	0.474	0.633	0.587	1.405	1.918	2.579	2.997	3.510	5.101	6.693	8.757	10.389
	0.224	0.475	0.612	0.759	1.087	1.476	1.951	2.563	2.951	3.426	4.902	6.377	8.328	9.804
1.60	0.165	0.486	0.660	0.854	1.296	1.763	2.386	3.173	3.678	4.297	6.197	8.155	10.593	12.856
	0.136	0.465	0.645	0.838	1.269	1.779	2.403	3.207	3.717	4.340	6.278	8.216	10.778	12.716
	0.275	0.591	0.762	0.945	1.353	1.836	2.427	3.168	3.671	4.262	6.058	7.933	10.360	12.195
1.80	0.253	0.642	0.854	1.107	1.557	2.213	2.575	3.949	4.529	5.289	7.592	9.937	12.888	15.124
	0.211	0.610	0.828	1.061	1.583	2.200	2.556	3.927	4.544	5.299	7.644	9.988	13.088	15.433
	0.344	0.729	0.939	1.165	1.668	2.264	2.592	3.932	4.527	5.256	7.320	9.783	12.776	15.039
2.00	0.342	0.817	1.059	1.380	1.987	2.760	3.683	4.817	5.593	6.550	9.376	12.197	16.032	18.469
	0.305	0.788	1.053	1.336	1.969	2.717	3.632	4.813	5.561	6.477	9.321	12.165	15.925	18.769
	0.422	0.894	1.152	1.428	2.045	2.775	3.669	4.821	5.551	6.444	9.220	11.995	15.664	18.440
2.20	0.448	1.040	1.354	1.660	2.466	3.379	4.471	5.936	6.888	8.035	11.232	14.832	19.158	22.853
	0.432	1.022	1.346	1.692	2.465	3.379	4.498	5.941	6.855	7.974	11.450	14.926	19.520	22.996
	0.515	1.091	1.407	1.745	2.458	3.390	4.482	5.889	6.780	7.872	11.262	14.652	19.134	22.524
2.40	0.575	1.301	1.675	2.070	3.008	4.100	5.460	7.224	8.332	9.680	13.645	17.809	23.738	27.231
	0.533	1.243	1.632	2.047	2.976	4.074	5.418	7.151	8.249	9.594	13.769	17.944	23.464	27.639
	0.628	1.330	1.715	2.126	3.044	4.131	5.461	7.175	8.262	9.592	13.723	17.854	23.315	27.446
2.60	0.729	1.584	2.048	2.561	3.672	5.059	6.687	8.809	10.121	11.658	16.645	21.655	28.242	33.846
	0.654	1.558	2.032	2.538	3.669	5.007	6.645	8.756	10.095	11.732	16.819	21.906	28.621	33.718
	0.764	1.618	2.086	2.566	3.704	5.026	6.644	8.730	10.052	11.670	16.695	21.721	28.365	33.391
2.80	0.850	1.931	2.498	3.105	4.486	6.182	8.175	10.776	12.225	14.256	20.407	26.726	35.757	42.808
	0.864	1.938	2.515	3.132	4.511	6.142	8.139	10.712	12.344	14.340	20.541	26.742	34.940	41.141
	0.925	1.967	2.535	3.143	4.502	6.109	8.075	10.611	12.218	14.184	20.293	26.402	34.417	40.586
3.00	1.121	2.340	3.036	3.773	5.460	7.539	9.830	12.889	14.826	17.378	24.827	32.112	43.109	51.064
	1.053	2.371	3.071	3.820	5.492	7.470	9.891	13.012	14.989	17.410	24.930	32.449	42.350	49.910
	1.128	2.389	3.080	3.819	5.469	7.422	9.811	12.851	14.843	17.232	24.654	32.075	41.866	49.307

TABLE G.1

Confidence Interval in case E

0.9-CONFIDENCE INTERVAL FOR QUANTILE

X-LEV	Q.5	CL	CU	Q.95	CL	CU	Q.98	CL	CU	Q.99	CL	CU
0.20	0.335	0.307	0.357	0.722	0.680	0.769	1.234	1.171	1.311	1.639	1.559	1.792
0.40	0.786	0.745	0.814	1.231	1.185	1.279	1.912	1.822	1.974	2.304	2.210	2.422
0.60	1.151	1.116	1.200	1.744	1.679	1.802	2.484	2.355	2.568	3.086	2.949	3.261
0.80	1.540	1.503	1.618	2.226	2.147	2.283	3.117	2.956	3.230	3.680	3.545	3.809
1.00	1.557	1.945	2.047	2.779	2.701	2.820	3.689	3.583	3.809	4.506	4.335	4.661
1.20	2.447	2.380	2.524	3.340	3.268	3.424	4.478	4.301	4.589	5.394	5.162	5.666
1.40	3.005	2.926	3.073	3.996	3.879	4.100	5.335	5.139	5.544	6.396	6.165	6.660
1.60	3.558	3.485	3.647	4.766	4.670	4.896	6.353	6.218	6.596	7.623	7.206	8.055
1.80	4.256	4.164	4.343	5.665	5.552	5.825	7.609	7.262	7.949	8.943	8.576	9.172
2.00	5.113	4.996	5.217	6.813	6.634	6.988	9.104	8.855	9.377	10.895	10.429	11.401
2.20	6.067	5.915	6.224	8.084	7.879	8.345	10.878	10.362	11.305	13.075	12.599	13.599
2.40	7.155	6.937	7.326	9.477	9.294	9.739	12.913	12.518	13.203	15.031	14.516	15.653
2.60	8.502	8.352	8.734	11.420	11.124	11.741	15.234	14.853	15.879	17.831	17.138	18.528
2.80	10.132	9.922	10.416	13.668	13.326	14.168	17.805	17.366	18.441	21.155	20.597	21.892
3.00	12.083	11.765	12.431	15.933	15.505	16.269	20.633	20.073	21.204	23.946	23.086	25.077

V. SIMULATION ALGORITHM

A. VARIABLE DEFINITION

$T_{X_i} = \{\inf t \geq 0 \; ; \; Z(t) \geq X_i\}$

where Z(t)=superposition of constant load and shock load

Nrow=maximum number of level X_i ; $X_1 < X_2 < X_3 < \ldots\ldots\ldots < X_{Nrow}$

Ncol=maximum number of repetition of generating T_x

Lc=constant load magnitude

Ls=shock load magnitude

Tc=constant load interval

Ts=shock load interval

Ipc=counting the number of repetition

I=counting the maximum level of X_i

B. ALGORITHM

```
Input;parameters ( λ, μ, a, b, seed numbers )
Initialize the stress level Xi ; X1<X2<X3<.........<XNrow
ipc=0
Repeat
    set T0=0
        M=0
        TTs=0
    Repeat
        generate constant load;Lc
        generate constant interval;Tc
        Find L such that L={sup i;Lc≥xi }
        Set Txi = T0  for 1≤i≤L
            M=L
            Ci=Tc
      A, generate the shock load;Ls
         generate the shock interval;Ts
      B, If Ts>Ci, then
```

```
                T0=T0+Tc
                Ts=Ts-Ci
                TTs=0
                generate constant load;Lc
                generate constant interval;Tc
                Find I such that L={sup i; Lc≥Xi}
                                    ≥M
                If L>M, then
                       Set Tx_i =T   for M<i≤L
                            M=L
                Else continue
                Ci=Tc
                Go to B
          Else, Find I such that L={sup i;Ls+Lc≥Xi }
                                    ≥M
                TTs=TTs+Ts
                Set Tx_i =T0+TTs for M<i≤L
                      Ci=Ci-Ts
                Go to A
        Until (L=Nrow)
        Ipc=Ipc+1
   Until (Ipc=Ncol)
   End Algorithm
```

APPENDIX A

COMPUTER PROGRAM

```
C    **********************************************************************
C
C    *****  VARIABLE DEFINITION  *****
C
C         TX=TIME OF COMBINATION LOAD EXCEEDS STRESS LEVEL X
C         X= STRESS LEVEL
C         NROW=MAXIMUM NUMBER OF STRESS LEVEL X
C         NCOL= MAXIMJM NUMBER OF REPLICATIONS OF GENERATING TX
C         CL= CCNSTANT LOAD MAGNITUDE
C         CI= CONSTANT LOAD INTERVAL
C         SL= SHCCK LOAD MAGNITUDE
C         SI= SHCCK LOAD INTERVAL
C         TTX = TRUE MEAN OF TX
C         ETX = SAMPLE MEAN OF TX
C         SK = VALUE OF KAPA
C         DENO = VALUE OF CONSTANT OF TAIL DISTRIBUTION TX
C         APRB = SAMPLE PROBABILITY OF TX=0
C         TTPR = TRUE PROBABILITY OF TX=0
C         IPC = COUNTING NUMBER OF REPETITION
C         RA1 = COSTANT LOAD ARRIVAL RATE
C         RA2 = CONSTANT LOAD MAGNITUDE PARAMETER; EXPONENTIAL(RA2)
C         RA3 = SHOCK LOAD ARRIVAL RATE
C         RA3 = SHOOK LOAD MAGNITUDE PARAMETER; EXPONENTIAL(RA4)
C
C    *********************************************************************
C
C       *****  MAIN PROGRAM  ******
C
        REAL*4 TX(25,5000),CL,CI,SL,SI,F1,F2,RA,XL,X(100)
      *,RA1,RA2,RA3,RA4,TTX(100),ETX(100),APRB(100),SK(100),F,DENO(100)
      *,TTPR(100),CC(100)
        INTEGER M,II,IPC,IFILE,NROW,NCOL
        RA1=1.0
        RA2=2.0
        RA3=1.0
        RA4=1.0
        F1=1.0/RA1
        F2=1.0/RA2
        F3=1.0/RA3
        F4=1.0/RA4
        IX1=27543
        IX2=25737
        IX3=27327
        IX4=23777
        DEL=0.5
        XL=0.0
        LC=1
        TO=0.0
```

```
      IPC=1
      NROW=10
      NCOL=500
      WRITE(6,117)RA1,RA2,RA3,RA4
117   FORMAT(1X,//,' ** INPUT DATA  **',/,1X,'CONSTANT-L ARRIVAL='
     *,F10.2,'(POISSON)'
     *,/,1X,'CONSTANT-L MAG=',F10.2,'(EXP)',/,1X,'SHOCK ARRIVAL RATE='
     *,F10.2,'(POISSON)',/,1X,'SHOCK-L MAG=',F10.2,'(EXP)')
      DO 100 I=1,NROW
        X(I)=XL+DEL
        XL=X(I)
100   CONTINUE
C
200   CALL RANDO(X,TX,LC,IPC,IX1,IX2,IX3,IX4,CL,CI,NROW,NCOL,TO
     *,F1,F2,F3,F4)
          IF(IPC.EQ.(NCOL+1))GO TO 900
            GO TO 200
900   CONTINUE
      CALL CCMPUT(X,TX,NROW,NCOL,XB,SD,PRB,VXB,VSD,RA1,RA2,RA3,RA4
     *,ETX,TTX,APRB,TTPR)
      CALL SORT(TX,NROW,NCOL)
      CALL CCMPU(X,TX,NROW,NCOL,ETX,TTX,XTX)
      CALL CCMP(X,TX,NROW,NCOL,ETX,TTX,APRB,STX,XXT)
      CALL SKAPA(X,SK,NROW,RA2,RA4)
      CALL INT(X,SK,NROW,DENO,RA2,RA4,TTX)
      CALL DCCMPU(X,TX,NROW,NCOL,ETX,TTX,SK,DENO,CC,RA2,RA4)
      STOP
      END
C
C ***************************************************************
C
C    ****   SUBFROGRAMS  ****
C
       SUBROUTINE CONST(IX1,IX2,CL,CI,F1,F2)
       REAL*4 CI,CL,F1,F2,A(1),B(1)
       INTEGER IX1,IX2
          CALL SEXPN(IX1,A,1,1,0)
          CI=A(1)*F1
          CALL SEXPN(IX2,B,1,1,0)
          CL=B(1)*F2
          RETURN
          END
C
       SUBROUTINE FINDA(X,CL,II,NROW)
        REAL*4 X(100),CL
        INTEGER II,K,NROW
        K=NROW
 11     IF(CL.GE.X(K))GO TO 101
```

```
      K=K-1
      IF(K.EQ.0)GO TO 101
      GO TC 11
101   II=K
      RETURN
      END
C
C
C
      SUBROUTINE STOREA(LC,II,IPC,TX,TO,NROW,NCOL)
       INTEGER N,IPC,II,NROW,NCOL
       REAL*4 TX(25,5000)
       IF(IPC.GE.(NCOL+1))GO TO 901
       N=II
       DO 110 I=LC,N
            TX(I,IPC)=TO
            IF(I.EQ.NROW)GO TO 111
110    CONTINUE
        LC=II+1
        GO TC 901
111    IPC=IPC+1
       TO=0.0
       LC=1
901      RETLRN
         END
C
C   ------ GENERATE THE TX ----------------------------------------
C
        SUBROUTINE RANDO(X,TX,LC,IPC,IX1,IX2,IX3,IX4,CL,CI,NROW,NCOL,TO
     *,F1,F2,F3,F4)
         REAL*4 CI,CL,TX(25,5000),C(1),D(1),X(100),TO,F1,F2,F3,F4,SD,S
         INTEGER IPC,LC,NROW,NCOL,IX1,IX2,IX3,IX4
         CALL CONST(IX1,IX2,CL,CI,F1,F2)
         II=0
         SD=C.0
         LC=1
         CDIST=CI
         IF(IPC.EQ.(NCOL+1))GO TO 909
         IF(CL.LT.X(LC))GO TO 10
            CALL FINDA(X,CL,II,NROW)
            CALL STOREA(LC,II,IPC,TX,TO,NROW,NCOL)
             IF(II.EQ.NROW)GO TO 909
 10      IF(IPC.EQ.(NCOL+1))GO TO 909
         IF(LC.GT.NROW)GO TO 901
         CALL SEXPN(IX3,C,1,1,0)
          SI=C(1)*F3
         CALL SEXPN(IX4,D,1,1,0)
          SL=D(1)*F4
```

```
 209     IF(SI.GT.CDIST)GO TO 902
          CCL=SL+CL
          SD=SD+SI
         IF(CCL.LT.X(LC))GO TO 201
 500        CALL FINDA(X,CCL,II,NROW)
 600         DO 110 K=LC,II
                TX(K,IPC)=TO+SD
 110         CONTINUE
             LC=II+1
             IF(LC.GT.NROW)GO TO 901
 201       CDIST=CDIST-SI
            GO TO 10
 902       SD=0.0
           TO=TO+CI
           SI=SI-CDIST
           CALL CONST(IX1,IX2,CL,CI,F1,F2)
           CDIST=CI
           IF(CL.LT.X(LC))GO TO 209
           CALL FINDA(X,CL,II,NROW)
           CALL STOREA(LC,II,IPC,TX,TO,NROW,NCOL)
           IF(II.EQ.NROW)GO TO 909
            GO TO 209
 901     TO=0.0
         LC=1
         SD=0.0
         SI=0.0
         CDIST=0.0
         CI=0.0
         CCL=0.0
         CL=0.0
         SL=0.0
         IPC=IPC+1
 909    RETURN
        END
C
C  ----- COMPUTE THE SAMPLE STATISTICS ----------------------
C
        SUBROUTINE COMPUT(X,TX,NROW,NCOL,XB,SD,PRB,VXB,VSD
     *,RA1,RA2,RA3,RA4,ETX,TTX,APRB,TTPR,STX)
         REAL*4 X(100),TX(25,5000),XB,SD,PRB,VXB,VSD,SUM,S2,S4
     *,TS1,TS4,SM4,U4,SM2,T,TM,TMA,TMB,RA1,RA2,RA3,RA4,ETX(100)
     *,TTX(100),STX(25,5000),CL,CU,APRB(100),TTPR(100),XN
         INTEGER NROW,NCOL,I,J,K,L,N
         WRITE(6,600)
 600     FORMAT(1X,//,1X,'X-LEV  P(TX=0)  TRUE PR',
     *4X,'X-BAR     T X-BAR   ST-DEVI  VAR(X-BAR)'
     *,' COEF-V   ',/)
         DO 100 I=1,NROW
```

```
      SUM=0.0
      DO 200 J=1,NCOL
         SUM=SUM+TX(I,J)
200   CONTINUE
      XB=SUM/FLOAT(NCOL)
      ETX(I)=XB
      S2=0.0
      S4=0.0
      DO 300 K=1,NCOL
        STX(I,K)=TX(I,K)
        TS2=(TX(I,K)-XB)**2
         S2=S2+TS2
        TS4=(TX(I,K)-XB)**4
         S4=S4+TS4
300   CONTINUE
      N=NCOL
      SD=(S2/FLOAT(N-1))**0.5
      SM2=S2/FLOAT(N)
      SM4=S4/FLOAT(N)
     U4=((S44*FLOAT(N*(N**2-2*N+3)))-(SM2**2*FLOAT(3*N*(2*N-3))))
      VSD=(U4-(SD**4))/(4*FLOAT(N-1)/SD**2)
      VXB=(SD**2)/N
      II=0
      DO 400 L=1,NCOL
C          STX=TX(I,L)
           IF(TX(I,L).EQ.0.0)GO TO 401
              GO TO 400
401        II=II+1
400   CONTINUE
      PRB=FLOAT(II)/FLOAT(NCOL)
      APRB(I)=PRB
      VPRB=(PRB*(1.0-PRB))/FLOAT(NCOL)
      CL1=PRB-1.645*SQRT(VPRB)
      CU1=PRB+1.645*SQRT(VPRB)
      TPR=EXP(-RA2*X(I))
      TTPR(I)=TPR
C ----- COMPUTE THE TRUE MEAN ---------------------------------------
C     * * F(X) AND G(X) ARE IDENTICAL EXPONENTIAL (A=B=1) * *
C          T=ALOG((RA1+RA3)/(RA1+RA3*EXP(-X(I))))
C        TMA=RA1*(1-EXP(-X(I)))-RA3*X(I)*EXP(-X(I))+RA3*EXP(-X(I))*T
C        TMB=1+(RA3/RA1)*X(I)-(RA3/RA1)*T
C        TM=(EXP(X(I))/(RA1**2))*(TMA/TMB)
C
C     * * F(X) AND G(X) ARE DIFFERENT EXPONENTIAL (A/B=2) * *
         XN=RA1*(-1.0+EXP(2.0*RA4*X(I)))+2.0*RA3*(1.0-EXP(RA4*X(I)))
     **+2.0*((RA3**2)/RA1)*(RA4*X(I)-ALOG((RA1+RA3)/(RA1+RA3*EXP(-RA4
     **X(I)))))
         TM=(1.0/RA1)*XN*(1.0/(RA1*EXP(2.0*RA4*X(I))-XN))
```

```
C           TTX(I)=XB
            TTX(I)=TM
            CL=XB-1.645*(VXB**0.5)
            CU=XB+1.645*(VXB**0.5)
            COV=SD/XB
           WRITE(6,709)X(I),PRB,TPR,XB,TM,SD,VXB,COV
 709       FORMAT(1X,F4.2,7F10.5,/)
 100    CONTINUE
        RETURN
        END
C
C  -----  COMPUTE THE QUANTILE  -----------------------------------
C
        SUBROUTINE COMPU(X,TX,NROW,NCOL,ETX,TTX,XTX)
           REAL*4 X(100),TX(25,5000),ETX(100),TTX(100),SK(100),DENO(100)
     *,P(15),Q(15),TQ(15),Q25,TQ25,Q75,TQ75,Q95
     *,TQ95,Q98,TQ98,Q99,TQ99,F1,XTX(50,10)
           INTEGER NROW,NCOL,I,J,L,NQ(15),N25,N75,N95,N98,N99
           WRITE(6,12)
  12      FORMAT(1X,/,1X,'    **   QUANTILE  OF  TX  **',
     *//,1X,'X-LEV   Q.1      Q.2      Q.25     Q.3      Q.4'
     *,5X,'Q.5      Q.6      Q.7      Q.75     Q.8      Q.9     Q.95'
     *,'      Q.98     Q.99',/)
          DO 101 I=1,9
              P(I)=0.1*FLOAT(I)
              QN=P(I)*FLOAT(NCOL)
              NQ(I)=IFIX(QN)
 101      CONTINUE
          DO 103 J=1,NROW
               DO 104 L=1,9
                   Q(L)=TX(J,NQ(L))
                   TQ(L)=-TTX(J)*ALOG(1.0-P(L))
 104           CONTINUE
              F1=FLOAT(NCOL)
               N25=IFIX(0.25*F1)
               N75=IFIX(0.75*F1)
               N95=IFIX(0.95*F1)
               N98=IFIX(0.98*F1)
               N99=IFIX(0.99*F1)
               Q25=TX(J,N25)
               TQ25=-TTX(J)*ALOG(1.0-0.25)
               Q75=TX(J,N75)
               TQ75=-TTX(J)*ALOG(1.0-0.75)
               Q95=TX(J,N95)
               TQ95=-TTX(J)*ALOG(1.0-0.95)
               Q98=TX(J,N98)
               TQ98=-TTX(J)*ALOG(1.0-0.98)
               Q99=TX(J,N99)
```

```
            TQ99=-TTX(J)*ALOG(1.0-0.99)
            XTX(J,1)=X(J)
            XTX(J,2)=ETX(J)
            XTX(J,3)=Q(9)
            XTX(J,4)=Q95
            XTX(J,5)=Q98
            XTX(J,6)=Q99
            XTX(J,7)=TQ(9)
            XTX(J,8)=TQ95
            XTX(J,9)=TQ98
            XTX(J,10)=TQ99
         WRITE(6,88)X(J),Q(1),Q(2),Q25,Q(3),Q(4),Q(5),Q(6),Q(7),Q75
     *,Q(8),Q(9),Q95,Q98,Q99
 88      FORMAT(1X,F5.2,14F8.3)
         WRITE(6,99)TQ(1),TQ(2),TQ25,TQ(3),TQ(4),TQ(5),TQ(6),TQ(7)
     *,TQ75,TQ(8),TQ(9),TQ95,TQ98,TQ99
 99      FORMAT(6X,14F8.3)
 103  CONTINUE
      RETURN
      END
C
C ----  COMPUTE THE  CONDITIONAL QUANTILE OF TX  ---------------
C
      SUBROUTINE COMP(X,TX,NROW,NCOL,ETX,TTX,APRB,STX,XXT)
        REAL*4 TX(25,5000),X(100),ETX(100),TTX(100),APRB(100),AP(15)
     *,AQ(15),ATQ(15),AQ25,ATQ25,AQ75,ATQ75,AQ95,ATQ95,AQ98
     *,ATQ98,AQ99,ATQ99,F,F1,XX(100),XXT(50,10)
        INTEGER NROW,NCOL,I,J,L,ANQ(15),AN25,AN75,AN95,AN98,AN99
         WRITE(6,12)
 12      FORMAT(1X,//,1X,'  **  CONDITIONAL QUANTILE OF  TX   **',
     *//,1X,'X-LEV    Q.1      Q.2      Q.25      Q.3      Q.4'
     *,5X,'Q.5     Q.6      Q.7      Q.75      Q.8      Q.9     Q.95'
     *,'    Q.98    Q.99',/)
      F=FLOAT(NCOL)
      DO 103 J=1,NROW
         NP1=IFIX(APRB(J)*F)
         NP2=NCOL-NP1
         DO 101 I=1,10
           AP(I)=0.1*FLOAT(I)
           AQN=AP(I)*FLOAT(NP2)
           ANQ(I)=NP1+IFIX(AQN)
 101     CONTINUE
         XX(J)=ETX(J)/(1.0-APRB(J))
         DO 102 L=1,9
          AQ(L)=TX(J,ANQ(L))
          ATQ(L)=(-XX(J))*ALOG(1.0-AP(L))
 102     CONTINUE
          F1=FLOAT(NP2)
```

```
      AN25=NP1+IFIX(0.25*F1)
      AN75=NP1+IFIX(0.75*F1)
      AN95=NP1+IFIX(0.95*F1)
      AN98=NP1+IFIX(0.98*F1)
      AN99=NP1+IFIX(0.99*F1)
      AQ25=TX(J,AN25)
      ATQ25=(-XX(J))*ALOG(1.0-0.25)
      AQ75=TX(J,AN75)
      ATQ75=(-XX(J))*ALOG(1.0-0.75)
      AQ95=TX(J,AN95)
      ATQ95=(-XX(J))*ALOG(1.0-0.95)
      AQ98=TX(J,AN98)
      ATQ98=(-XX(J))*ALOG(1.0-0.98)
      AQ99=TX(J,AN99)
      ATQ99=(-XX(J))*ALOG(1.0-0.99)
      XXT(J,1)=X(J)
      XXT(J,2)=ETX(J)
      XXT(J,3)=AQ(9)
      XXT(J,4)=AQ95
      XXT(J,5)=AQ98
      XXT(J,6)=AQ99
      XXT(J,7)=ATQ(9)
      XXT(J,8)=ATQ95
      XXT(J,9)=ATQ98
      XXT(J,10)=ATQ99
      WRITE(6,990)X(J),AQ(1),AQ(2),AQ25,AQ(3),AQ(4)
     *,AQ(5),AQ(6),AQ(7),AQ75,AQ(8),AQ(9),AQ95,AQ98,AQ99
990   FORMAT(1X,F5.2,14F8.3)
      WRITE(6,999)ATQ(1),ATQ(2),ATQ25,ATQ(3),ATQ(4)
     *,ATQ(5),ATQ(6)
     *,ATQ(7),ATQ75,ATQ(8),ATQ(9),ATQ95,ATQ98,ATQ99
999   FORMAT(6X,14F8.3)
103   CONTINUE
      RETURN
      END
C
C ----  COMPLTE THE QUANTILE OF TAIL DISTRIBUTION  --------------
C
      SUBROUTINE DCOMPU(X,TX,NROW,NCOL,ETX,TTX,SK,DENO
     *,CC,RA2,RA4)
      REAL*4 X(100),TX(25,5000),ETX(100),TTX(100)
     *,P(15),C(15),TQ(15),STQ(15),Q25,TQ25,STQ25,Q75,TQ75
     *,TQ95,STQ95,Q98,TQ98,STQ98,Q99,TQ99,STQ99,F1,SL(100)
     *,RA4,ATQ(15),ATQ25,ATQ75,ATQ95,ATQ98,ATQ98,ATQ99
     *,SK(100),DENO(100),STQ75,Q95,CC(100),RA2
      INTEGER NROW,NCOL,I,J,L,NQ(15),N25,N75,N95,N98,N99
      WRITE(6,12)
12    FORMAT(1X,//,1X,'  ***   QUANTILE (COMPARING TAIL'
```

```
     *,' DIST CF TX)   ***   ',//,1X,'X-LEV    C.1      Q.2'
     *,5X,'Q.25      Q.3      Q.4      Q.5      Q.6      Q.7'
     *,'    C.75      Q.8      Q.9      Q.95     Q.98     Q.99',/)
      DO 101 I=1,9
         P(I)=0.1*FLOAT(I)
         CN=P(I)*FLOAT(NCOL)
         NQ(I)=IFIX(QN)
101   CONTINUE
      DO 103 J=1,NROW
         DO 104 L=1,9
            Q(L)=TX(J,NQ(L))
            TQ(L)=-TTX(J)*ALOG(1.0-P(L))
        ATC(L)=(-1.0/SK(J))*ALOG(1.0-P(L))
        STC(L)=(-1.0/SK(J))*ALOG((1.0-P(L))*DENO(J))
        IF(STQ(L).GT.0.0)GO TO 104
         STQ(L)=0.0
104      CONTINUE
        F1=FLOAT(NCOL)
         N25=IFIX(0.25*F1)
         N75=IFIX(0.75*F1)
         N95=IFIX(0.95*F1)
         N98=IFIX(0.98*F1)
         N99=IFIX(0.99*F1)
         C25=TX(J,N25)
         TQ25=-TTX(J)*ALOG(1.0-0.25)
        ATC25=(-1.0/SK(J))*ALOG(1.0-.25)
        STC25=(-1.0/SK(J))*ALOG((1.0-.25)*DENO(J))
         IF(STQ25.GT.0.0)GO TO 75
           STQ25=0.0
 75      Q75=TX(J,N75)
         TQ75=-TTX(J)*ALOG(1.0-0.75)
        ATC75=(-1.0/SK(J))*ALOG(1.0-0.75)
        STC75=(-1.0/SK(J))*ALOG((1.0-.75)*DENO(J))
          IF(STQ75.GT.0.0)GO TO 95
           STQ75=0.0
95       C95=TX(J,N95)
         TQ95=-TTX(J)*ALOG(1.0-0.95)
        ATC95=(-1.0/SK(J))*ALOG(1.0-0.95)
        STC95=(-1.0/SK(J))*ALOG((1.0-.95)*CENO(J))
         Q98=TX(J,N98)
         TQ98=-TTX(J)*ALOG(1.0-0.98)
        ATC98=(-1.0/SK(J))*ALOG(1.0-0.98)
        STC98=(-1.0/SK(J))*ALOG((1.0-.98)*DENO(J))
         C99=TX(J,N99)
         TQ99=-TTX(J)*ALOG(1.0-0.99)
        ATC99=(-1.0/SK(J))*ALOG(1.0-0.99)
        STC99=(-1.0/SK(J))*ALOG((1.0-0.99)*DENL(J))
        WRITE(6,88)X(J),Q(1),Q(2),Q25,Q(3),Q(4),Q(5)
```

```
     *,Q(6),C(7),C75,C(8),Q(9),Q95,Q98,Q99
 88        FORMAT(1X,F5.2,14F8.3)
            WRITE(6,109)STQ(1),STQ(2),STQ25,STQ(3),STQ(4)
     *,STQ(5),STQ(6)
     *,STQ(7),STQ75,STQ(8),STQ(9),STQ95,STQ98,STQ99
 109        FORMAT(6X,14F8.3)
            WRITE(6,99)TQ(1),TQ(2),TQ25,TQ(3),TQ(4),TQ(5)
     *,TQ(6),TQ(7),TQ75,TQ(8),TQ(9),TQ95,TQ98,TQ99
  99        FORMAT(6X,14F8.3,/)
 103     CONTINUE
         RETURN
         END
C
         SUBROUTINE SORT(AA,NROW,NCOL)
         REAL*4 AA(25,5000),A(5000),B(5000)
         INTEGER NROW,NCOL
        DO 30 I =1,NROW
            DO 40 J =1,NCOL
                A(J) = AA(I,J)
                B(J) = AA(I,J)
 40         CONTINUE
            CALL SHSORT(A,B,NCOL)
            DO 50 K = 1,NCOL
                 AA(I,K) = A(K)
 50         CONTINUE
 30     CONTINUE
         RETURN
         END
C
C  ---   COMPUTE THE KAPA   ---------------------------------
C
         SUBROUTINE SKAPA(X,SK,NROW,RA2,RA4)
          REAL*4 X(100),SK(100),R,TL,TR,P,TNEW,CHECK,RA2,RA4
          INTEGER I,IC,NROW
          IC=0
          DO 100 I=1,NROW
            IC=IC+1
            R=X(I)
            TL=0.0
            TR=1.0+EXP(-RA4*R)-0.001
  5         TNEW=(TL+TR)/2.0
            P=CCM(TNEW,R,RA2,RA4)
            CHECK=ABS(P-1.0)
            IF(CHECK.LT.0.001)GO TO 90
            IF(IC.GT.100)GO TO 80
            IF(P.GT.1.0)GO TO 50
              TL=TNEW
              TR=TR
```

```
         GC TO 5
50      TL=TL
        TR=TNEW
       GO TC 5
80     WRITE(6,21)
21     FORMAT(1X,'**')
90     SK(I)=TNEW
100   CONTINUE
       RETURN
       END
C
C ----  COMPUTE THE FUNCTION F(K)------------------------------
C
       FUNCTION COM(TNEW,R,RA2,RA4)
       REAL*4 R,TNEW
        IF(TNEW.EQ.1.0)GO TO 23
       COM=(2.0/(1.0-TNEW)**3)*((0.5*((1.0-TNEW)+EXP
     *(-RA4*R))**2)
     *-(0.5*((1.0-TNEW)*EXP(-RA4*R)+EXP(-RA4*R))**2)
     *-2.0*EXP(-RA4*R)*(1.0-TNEW)*(1.0-EXP(-RA4*R))
     *+EXP(-2.0*RA4*R)*(ALOG(1.0-TNEW
     *+EXP(-RA4*R))-ALOG((2.0-TNEW)*EXP(-RA4*R))))
        GO TO 45
23     COM=((RA2)/(RA2+RA4))*(EXP(RA4*R)-EXP(-RA2*R))
45      RETURN
        ENC
C
C ----  COMPUTE THE CONSTANT OF TAIL DISTRIBUTION  -----------------
C
      SUBRCUTINE INT(X,SK,NROW,DENO,RA2,RA4,TTX)
      REAL*4 X(100),SK(100),DENO(100),RA2,RA4,TTX(100)
     *,R,RR,RRR,ATTX(100)
      REAL*8 SA,B,AA,BB,DRA4,W
      INTEGER IER,IC,NROW
      DO 123 I=1,NROW
        DRA4=DBLE(RA4)
        SA=CBLE(SK(I))
        B=CBLE(X(I))
        AA=1.DO-SA+DEXP(-DRA4*B)
        BB=DEXP(-DRA4*B)*(2.DO-SA)
        W=(2.DO/((1.DO-SA)**4))*(((AA**2)/2.DO)-((BB**2)/2.DO)-3.DO*
     *DEXP(-CRA4*B)*((1.DO-SA)*(1.DO-DEXP(-DRA4*B)))+3.DO*DEXP(-2.DO*
     *DRA4*B)*(DLOG(AA)-CLOG(BB))-DEXP(-3.DO*DRA4*B)*((1.DO/BB)-(1.DO
     */AA)))
        DENC(I)=SNGL(W)
        ATTX(I)=1.0/TTX(I)
123   CONTINUE
```

```
      WRITE(6,125)(X(I),I=1,NROW)
125   FORMAT(/,1X,'**    (X),    1/E(TX),    (X)   ** ',//,1X,'X-LEV '
     *,15F7.3,/)
      WRITE(6,126)(SK(I),I=1,NROW)
126   FORMAT(1X,' (X)   ',15F7.3,/)
      WRITE(6,128)(ATTX(I),I=1,NROW)
128   FORMAT(1X,'1/E(T) ',15F7.3,/)
      WRITE(6,127)(DENO(I),I=1,NROW)
127   FORMAT(1X,'  (X) ',15F7.3,//////////)
      RETURN
      END
```

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